RETROFITTING A CITY SCHOOL

Our Lady of Perpetual Help; Toronto, Canada

Solar Decathlon
U.S. Department of Energy
Elementary School Division

reGeneration
Ryerson University

reGeneration

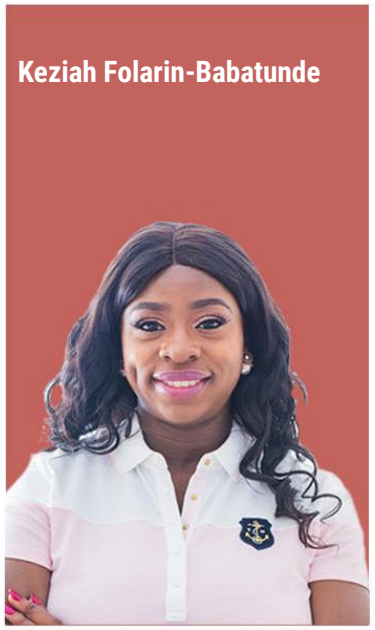
Mark Gorgolewski, PhD
Faculty Lead
Department of Architectural Science

Hayes Zirnhelt, MASc
Technical Advisor
Department of Architectural Science

Building Envelope Lead
1st year, MBSc
Background: Civil engineering

Architecture Lead
1st year, MBSc
Background: Architecture

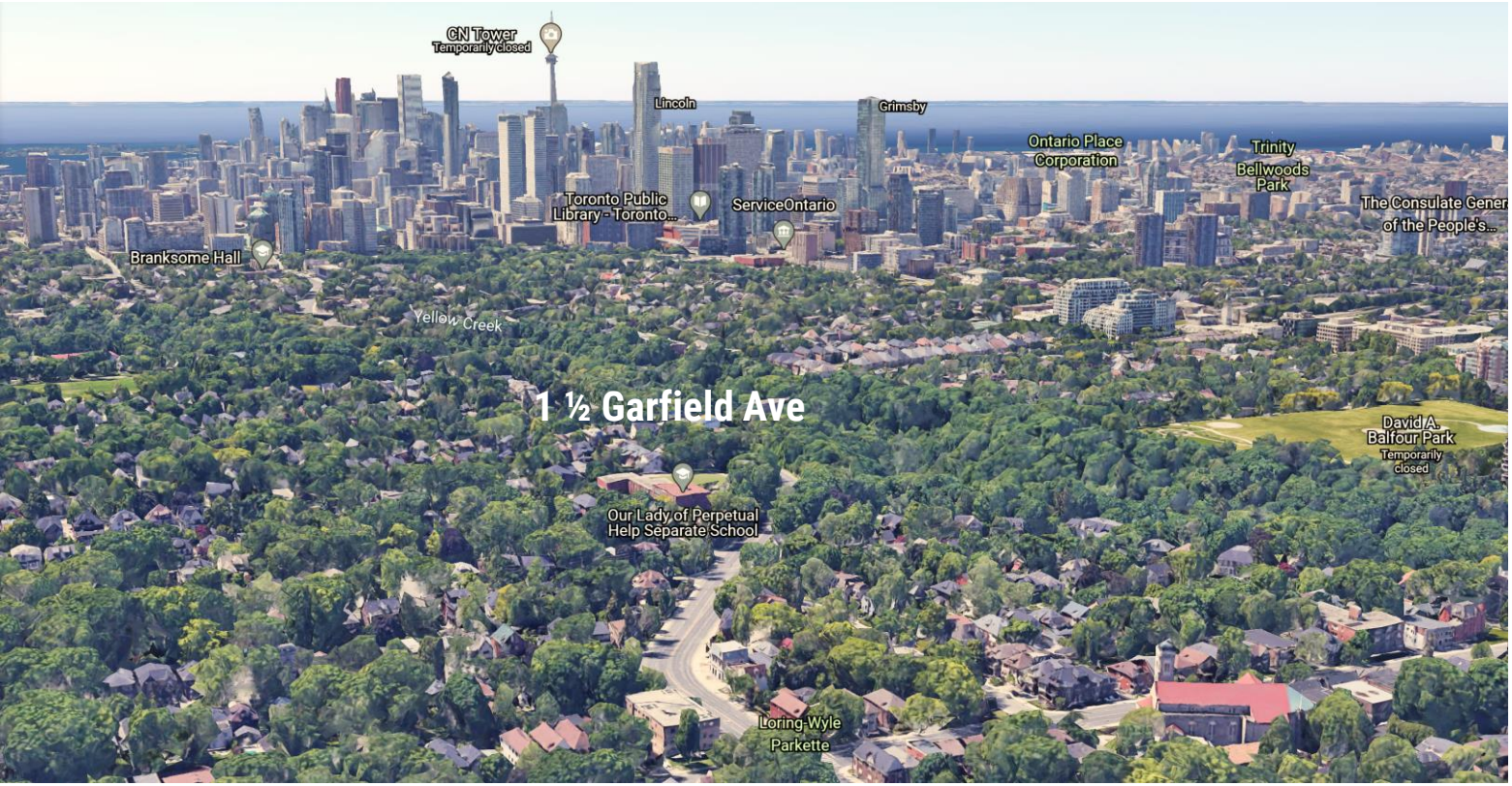
HVAC + Renewable Energy Lead
1st year, MASc
Background:
Chemical engineering



Project Management Lead
1st year. MBSc
Background: Building Construction + Construction Project Management

Energy Modelling Lead
1st Year. MBSc
Background: Architecture

Project Introduction



Don Valley Brick Works Beltline

David A. Balfour Trail

Considering a growing population…

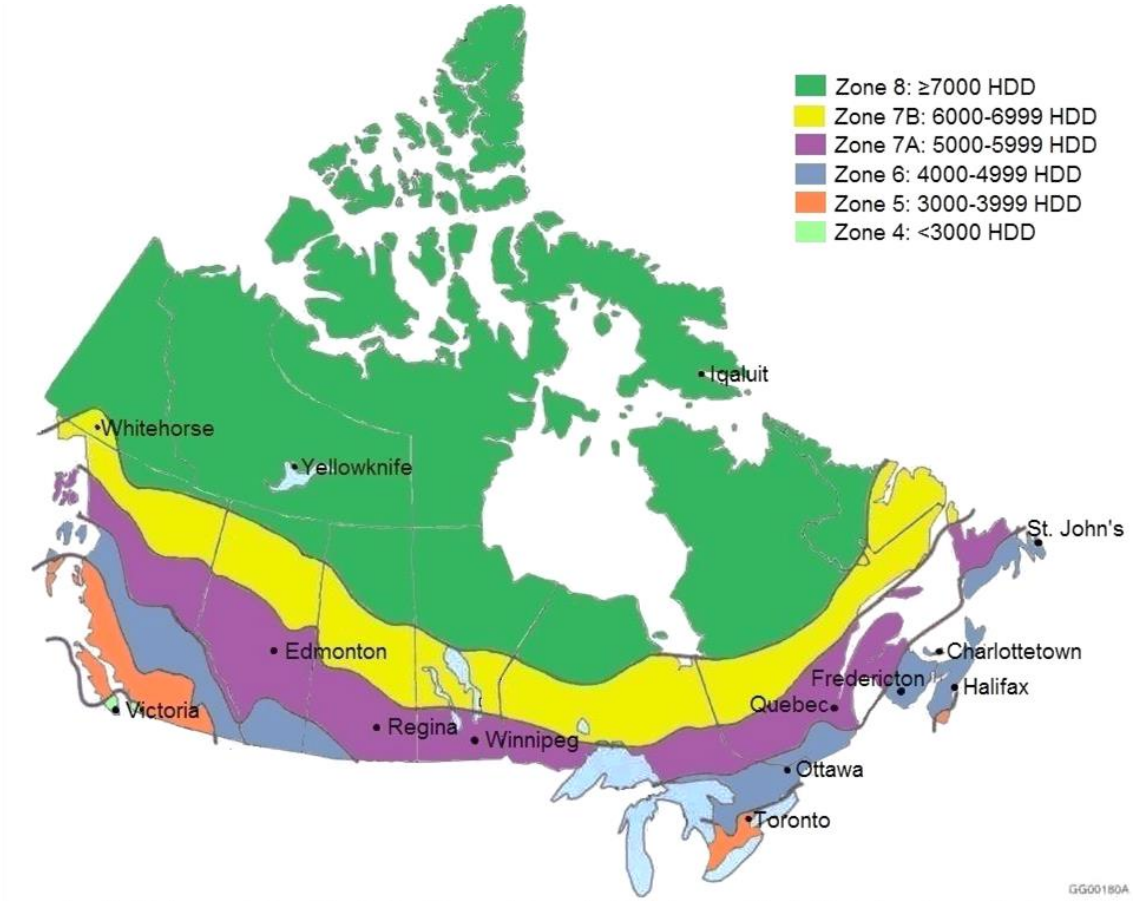
Design is for a 12% growth over the next 10 years
440 occupants: 400 students ages 4 to 13, 40 staff

Target market includes:

Occupants and community

Local school board (TCDSB)

Stakeholders in construction industry



Local Climate

Cold Climate in Toronto
ASHRAE Zone 5A

Standards

Ontario Building Code – 2019
ASHRAE 90.1 and 62.1 – 2019
Toronto Green Standard (Tier 3)

Minimizing embodied + operational carbon

Minimizing energy consumption

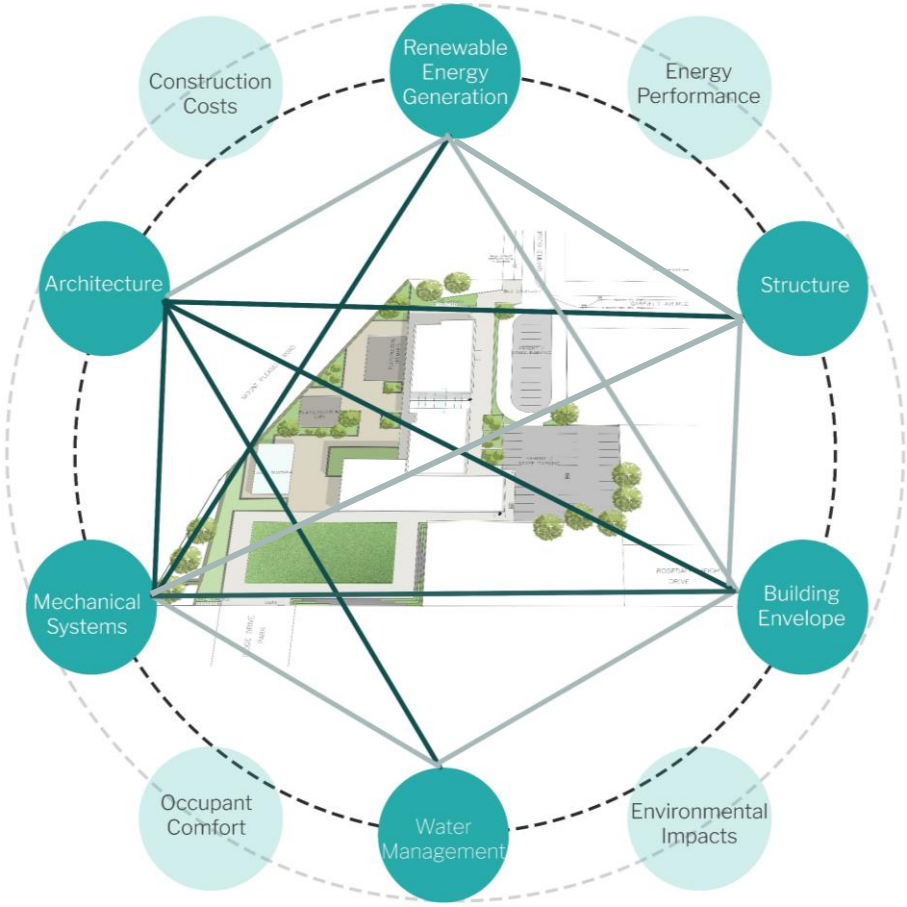
Maximizing usable space after retrofit

Responsible water management

Optimal occupant comfort + wellbeing

Enhanced occupant experience

Community integration

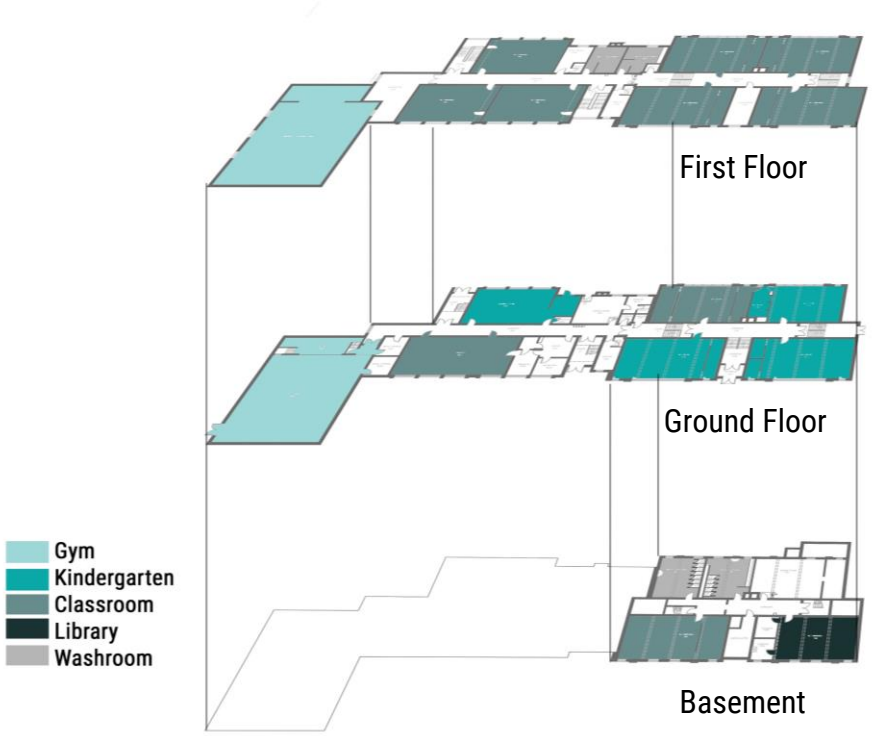


Existing Building
Proposed Redesign

Architecture
Engineering
Comfort and Environmental Quality
Energy Performance
Embodied Environmental Impact
Durability and Resilience
Market Analysis
Occupant Experience

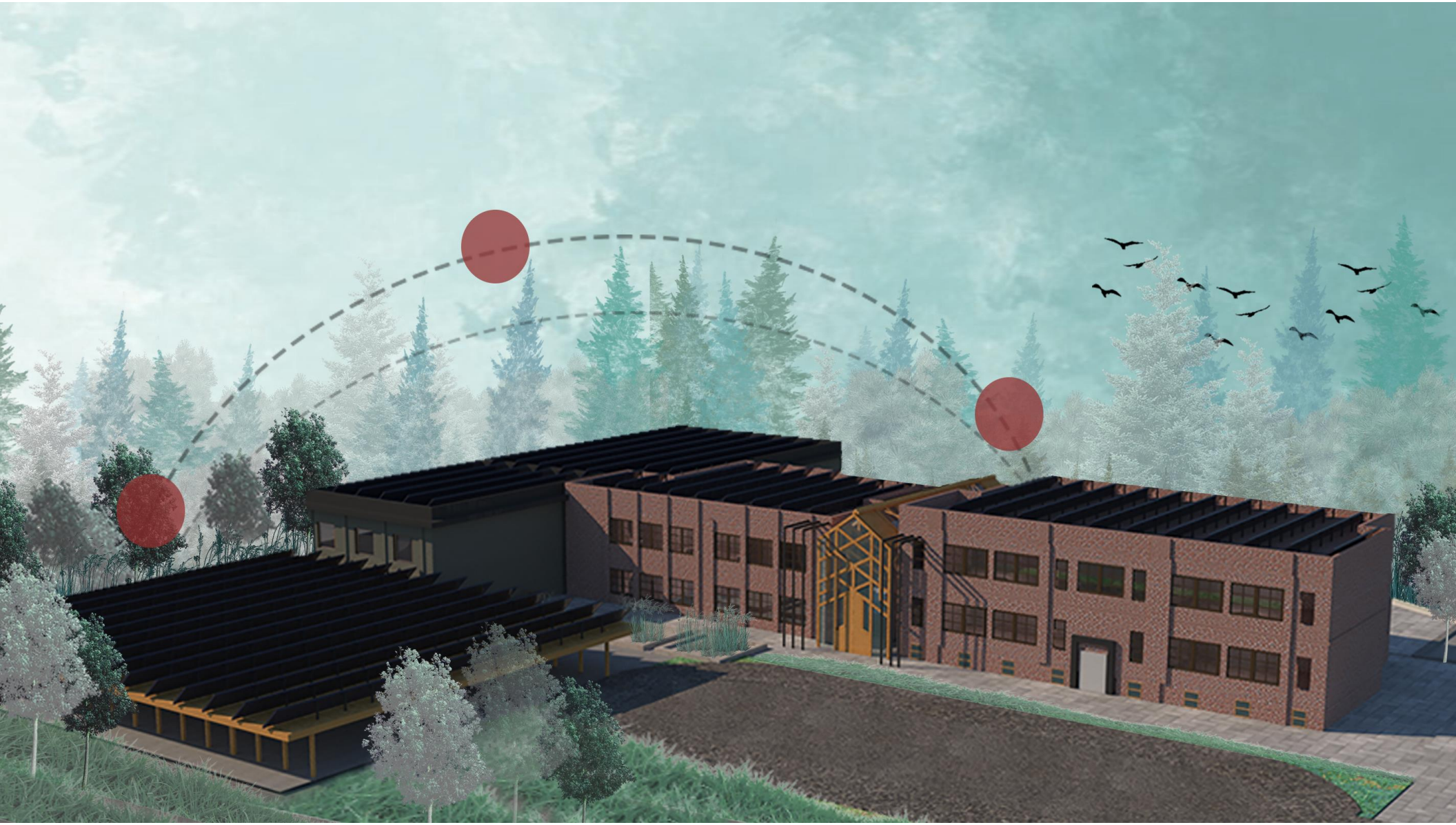
Architecture

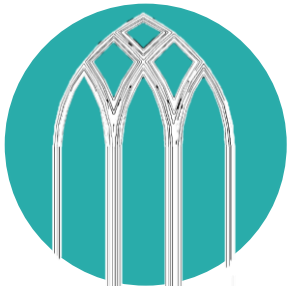
Existing Building

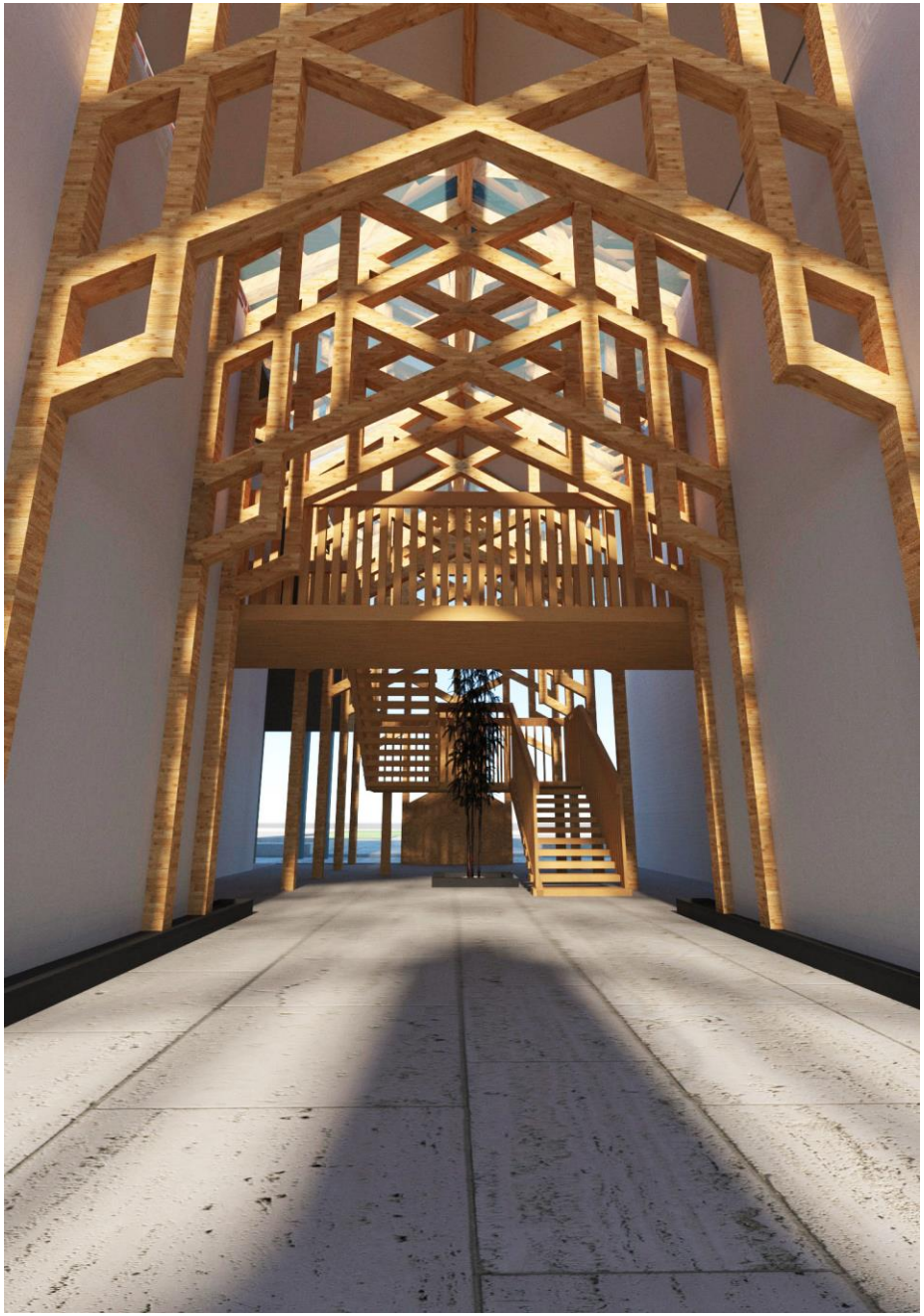

Gym
Kindergarten
Classroom
Library
Washroom
First Floor
Ground Floor
Basement

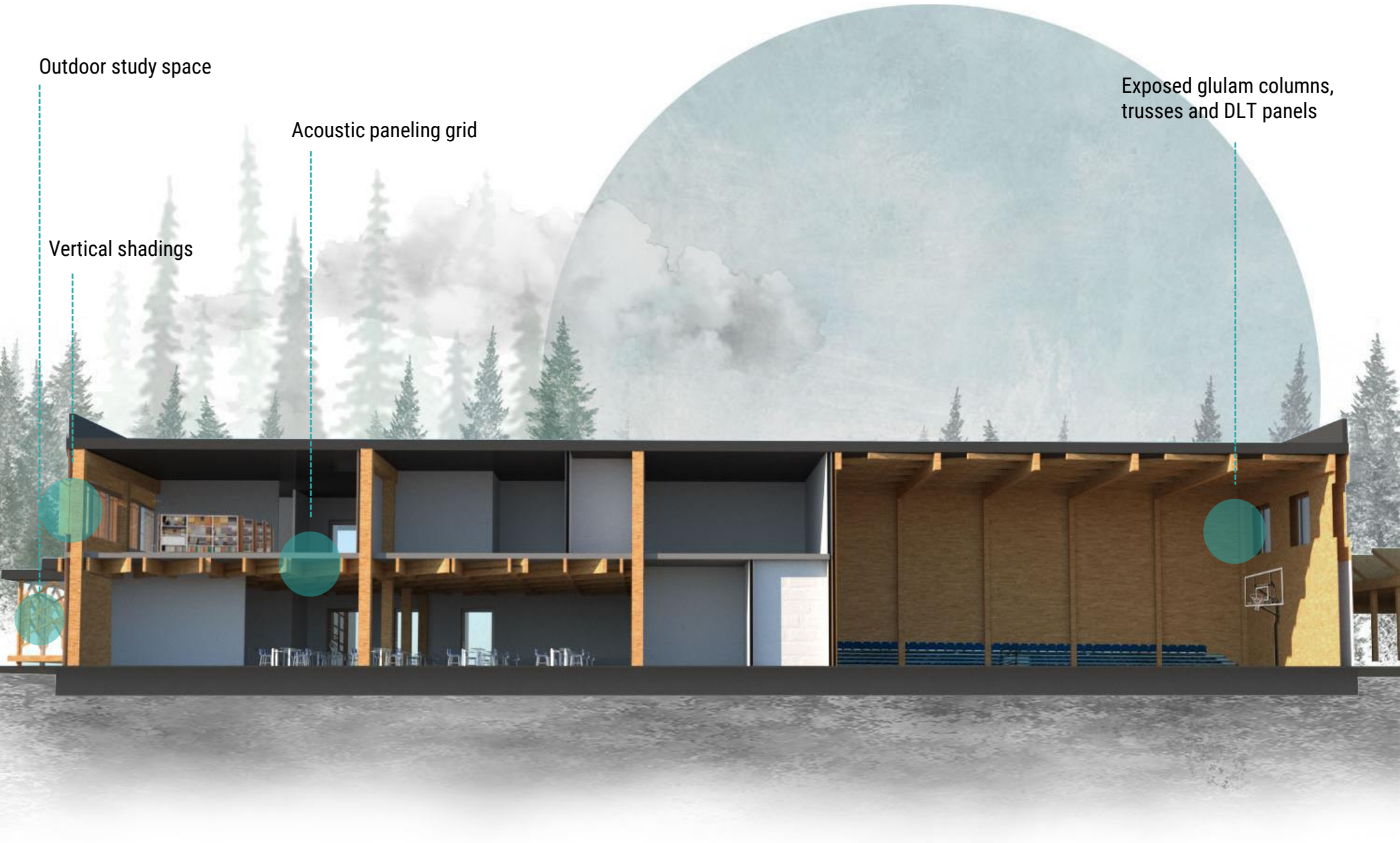
Architecture

Proposed Redesign








Outdoor study space
Acoustic paneling grid
Vertical shadings
Exposed glulam columns,
trusses and DLT panels

Building Structure
Building Envelope
Water Systems
Mechanical Systems
Renewables

- **Architecture**
- **Engineering**
- **Comfort and Environmental Quality**
- **Energy Performance**
- **Embodied Environmental Impact**
- **Durability and Resilience**
- **Market Analysis**
- **Occupant Experience**

Engineering

Building Structure

Original structure

- Triple-wythe mass masonry
- Wood-framed roofs
- Wood-framed or concrete floors

New extension structure

- Glulam columns
- Glulam floor and roof joists
- Dowel-laminated timber (DLT) panels

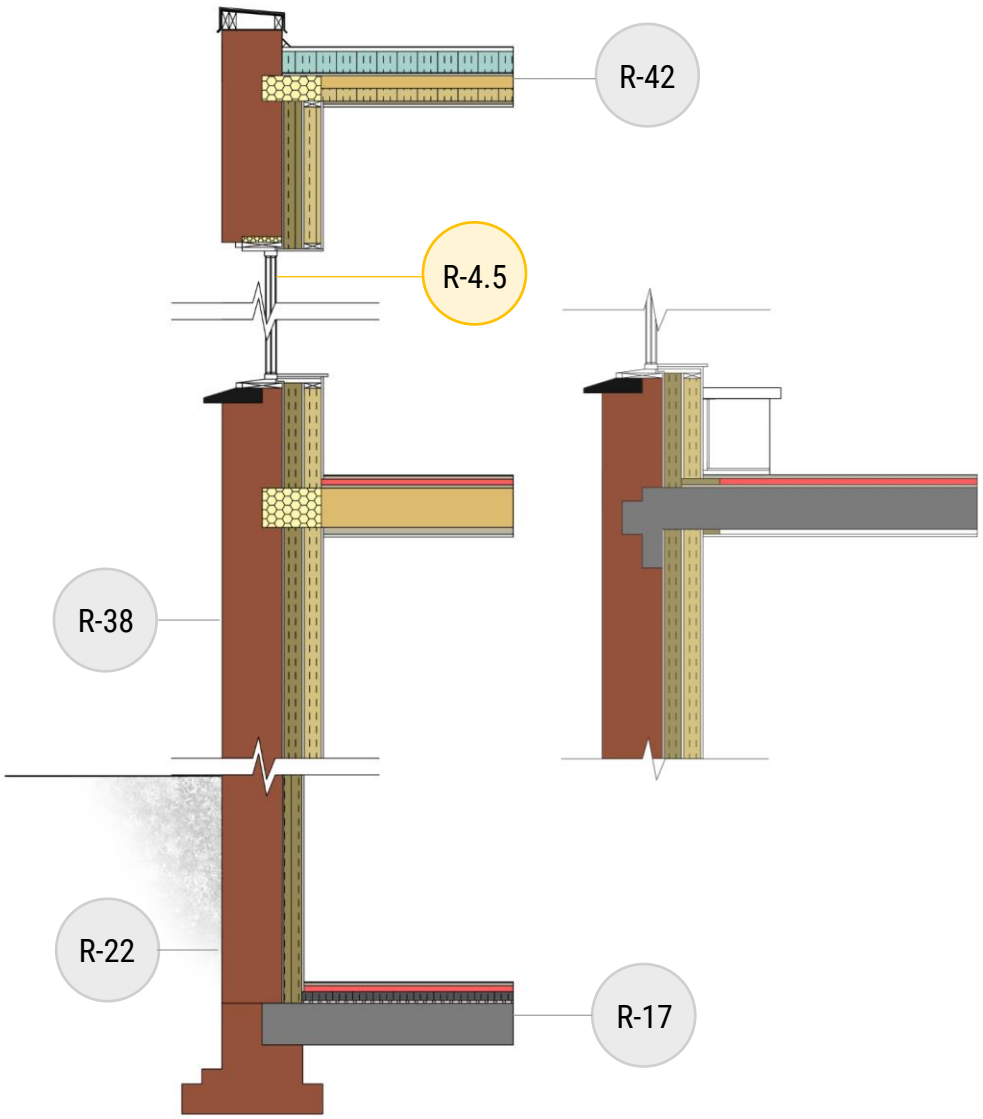
New atrium structure

- Glulam trusses
- Glulam-framed curtain wall
- Dowel-laminated timber (DLT) roof panels

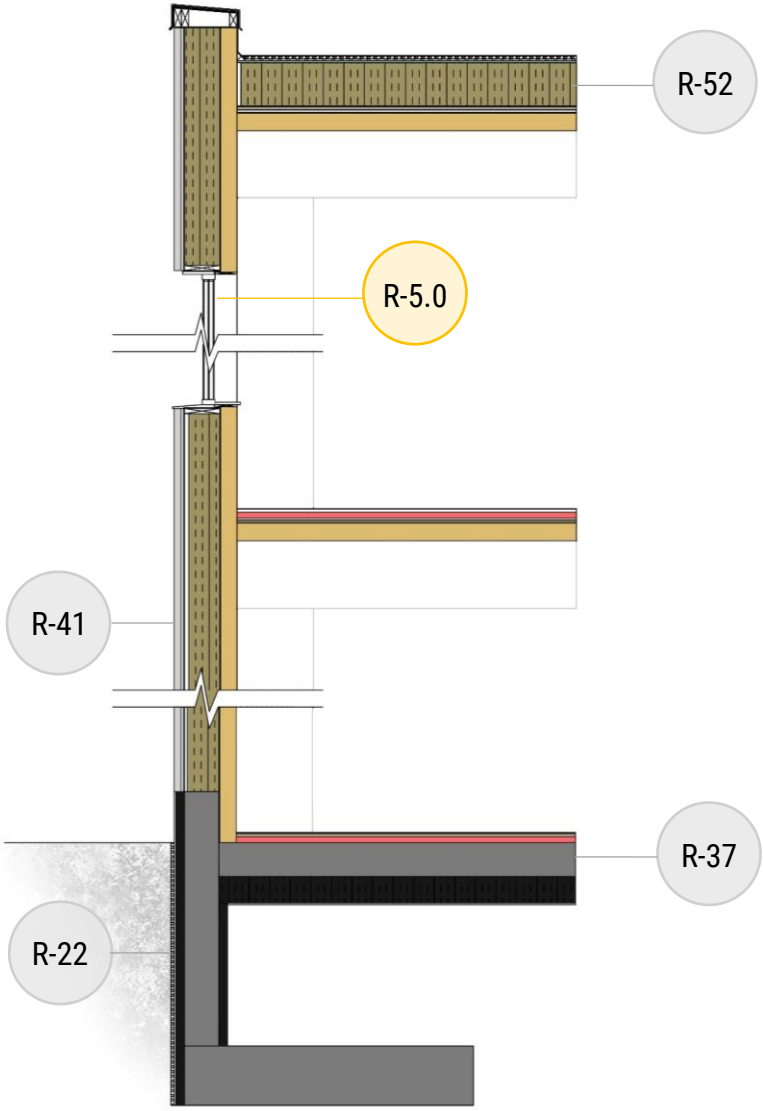
Engineering

Building Envelope

Retrofit envelope



New extension envelope



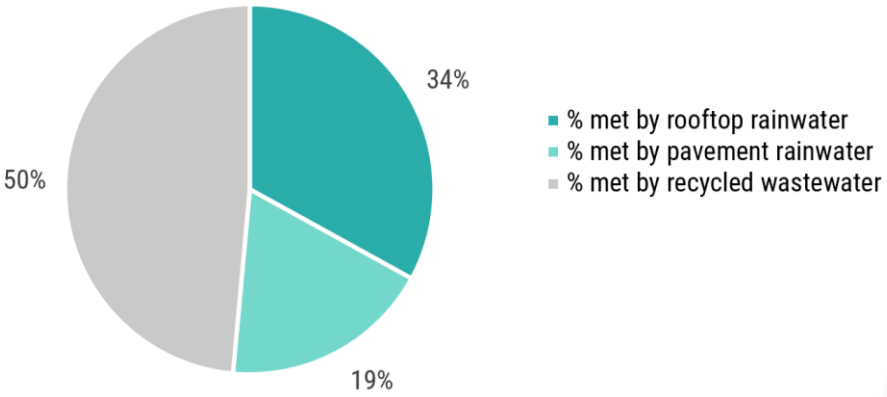
Engineering

Water Systems

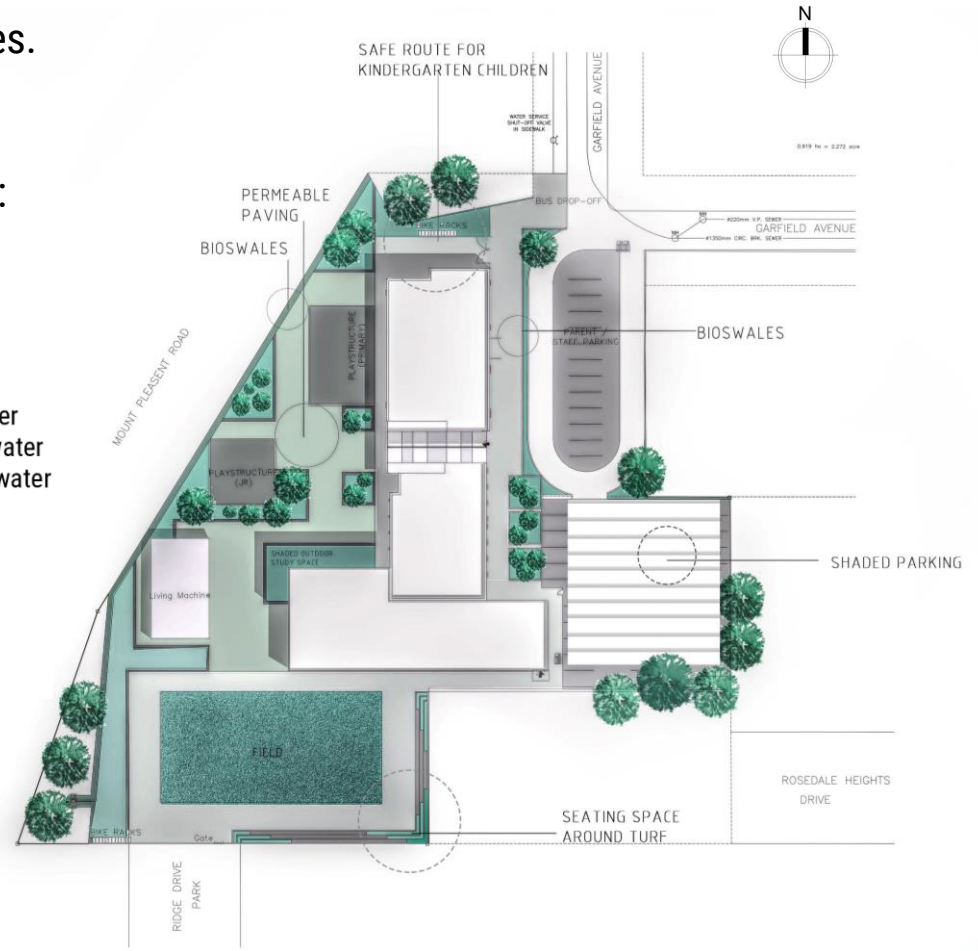
Responsible water management

1. Conserving water
Water demand **reduced** by 52% with new fixtures.

2. Recycling water
All non-potable demand met by water recycling:



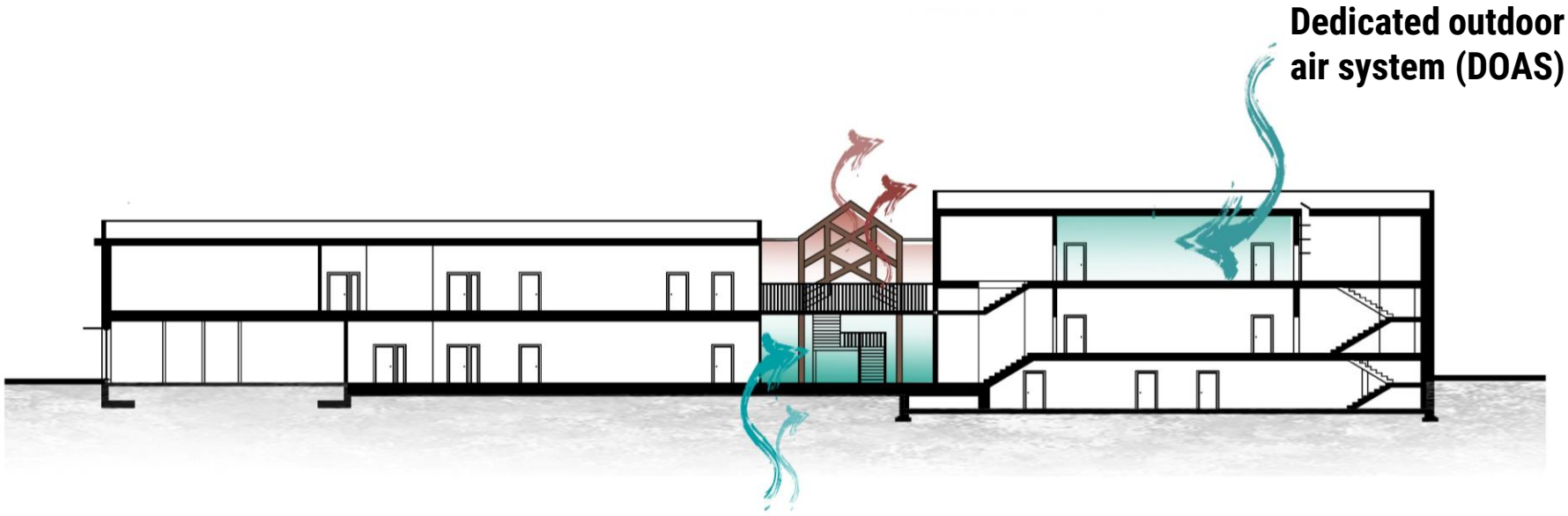
3. Restoring natural cycles
Bioswales reduce stormwater runoff while returning water to natural aquifers.



Engineering

Mechanical Systems

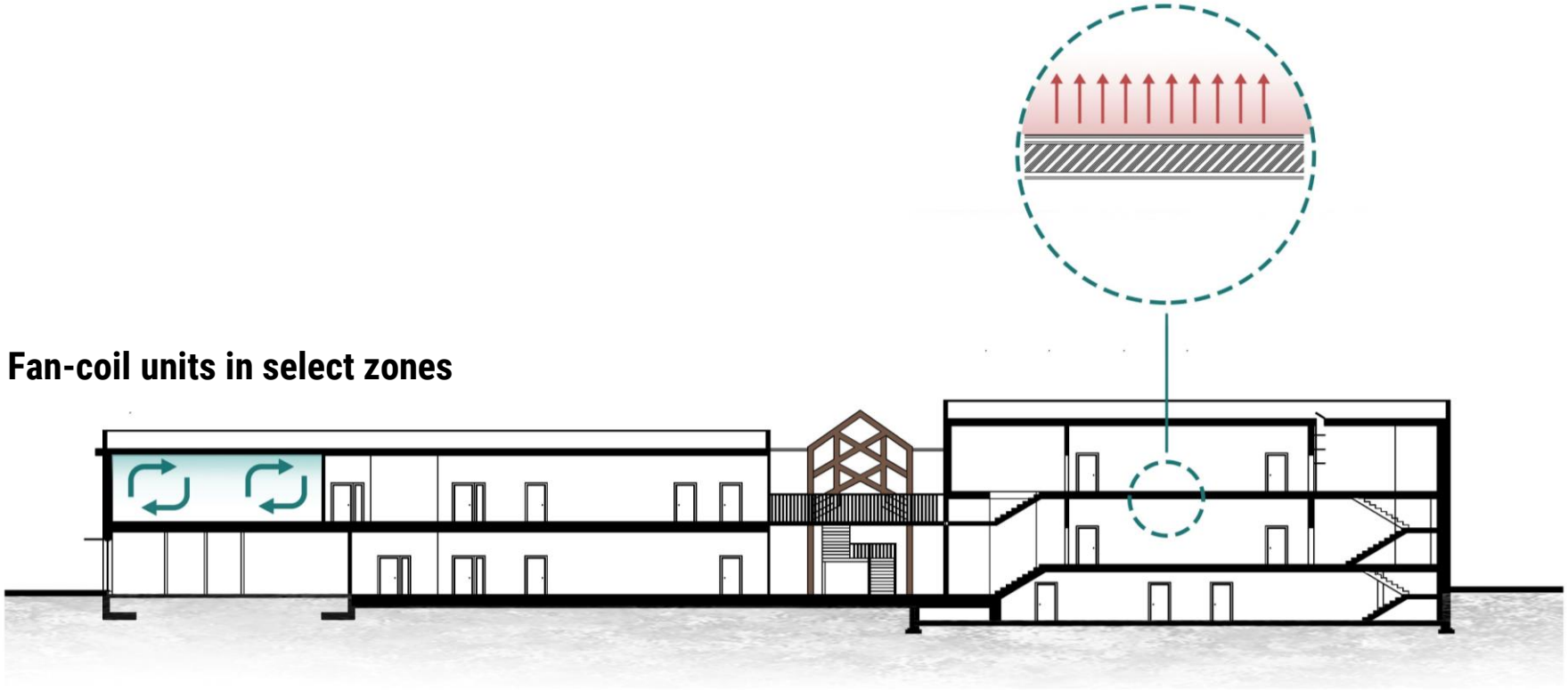
Hybrid ventilation strategy



Heating + cooling

Radiant in-floor heating

Fan-coil units in select zones



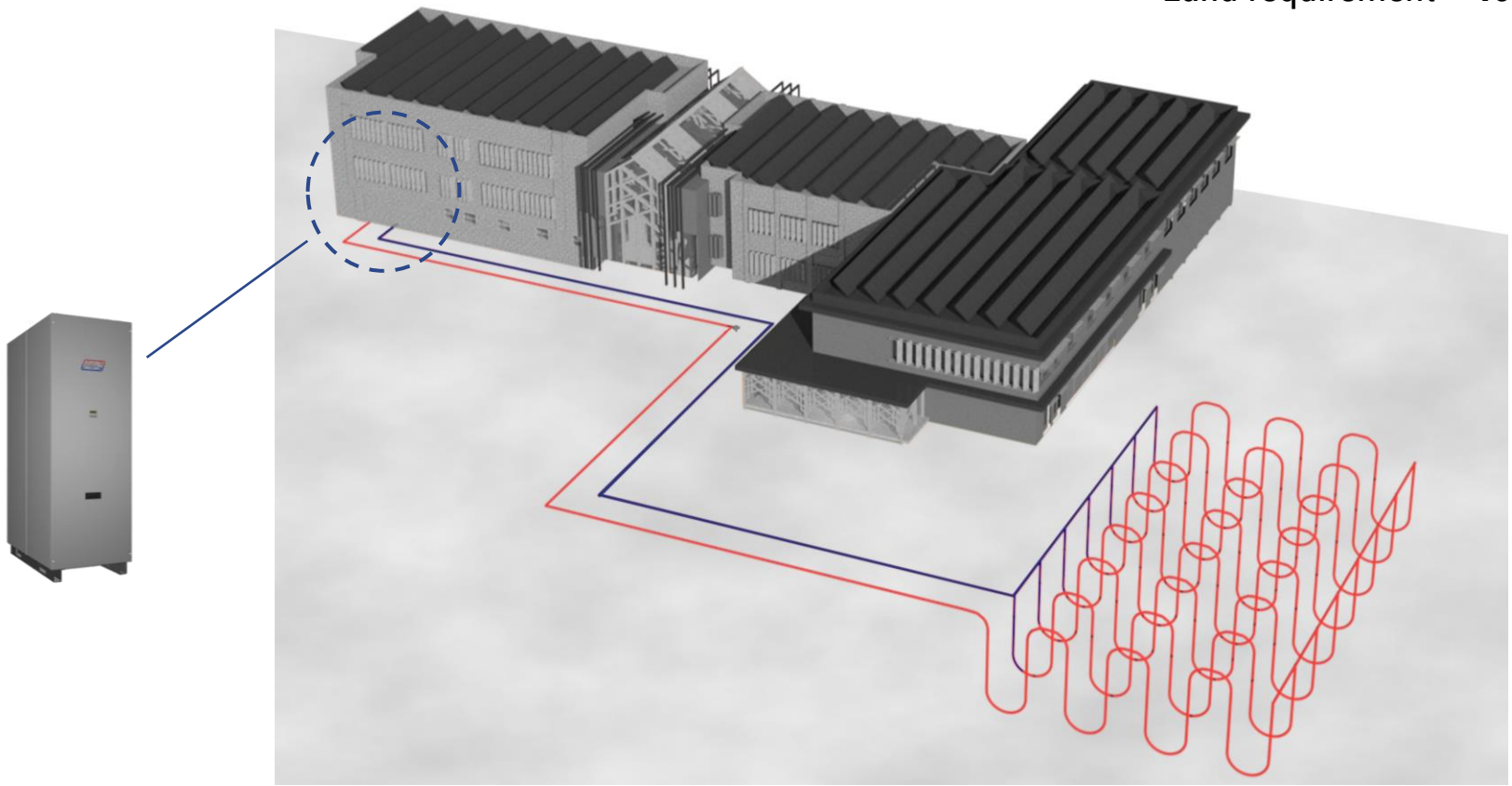
Cooling loads driven down by:

- DOAS cooling coil
- Window shadings
- Roof PV shading
- Operable windows

Engineering
Renewables

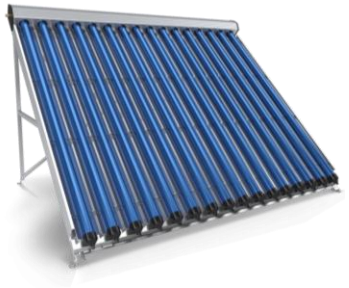
Geothermal generation

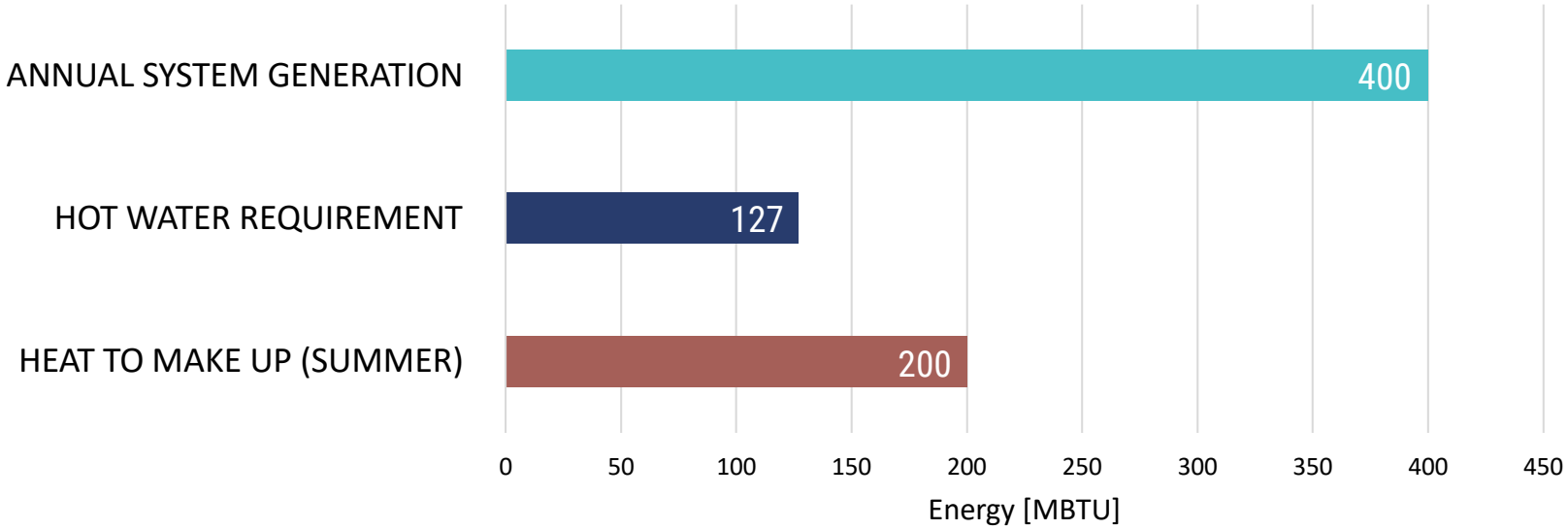
Annual heating demand	240 MBTU
Annual cooling demand	40 MBTU
System size	19 tons
Land requirement	4640 sqft



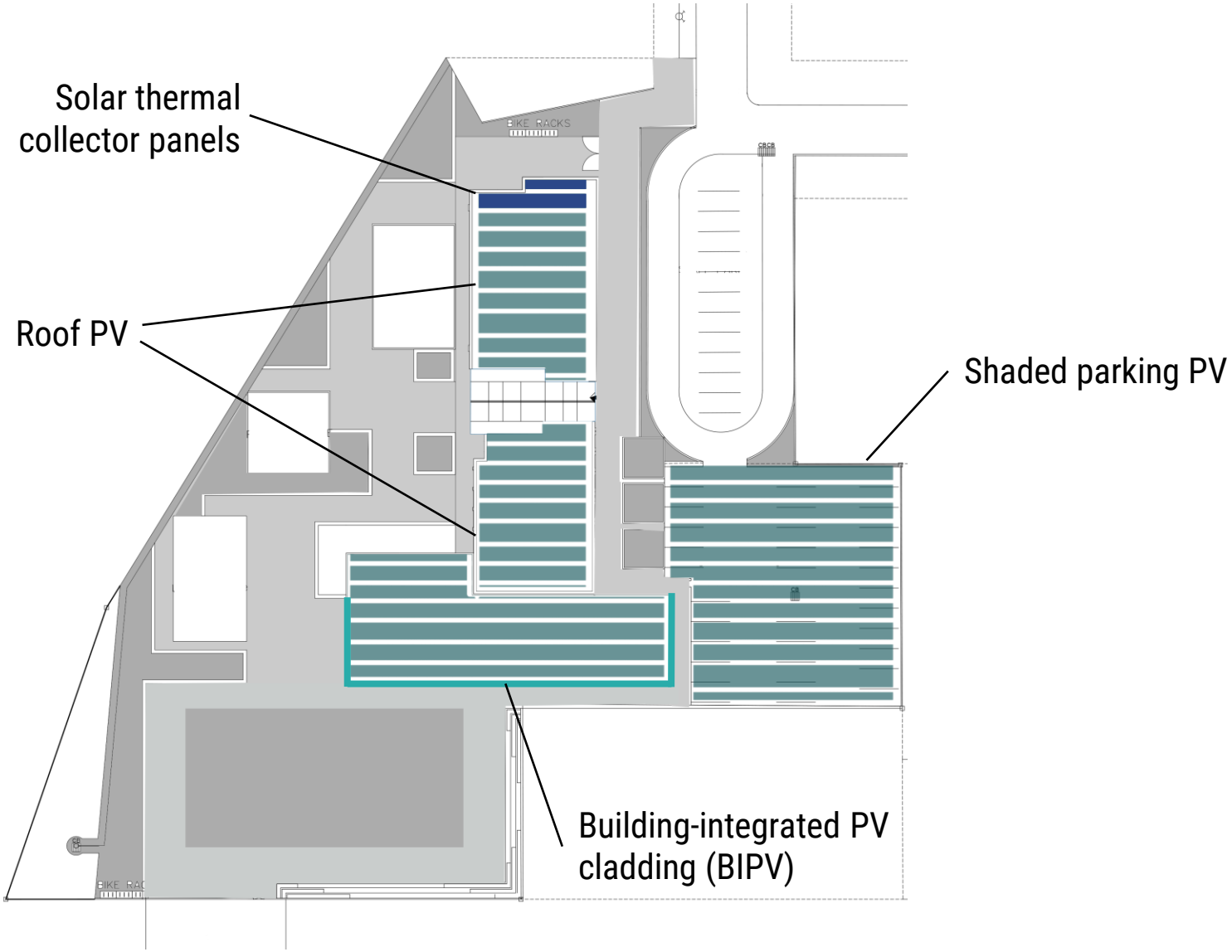
Solar thermal energy

Tilt angle: 30°

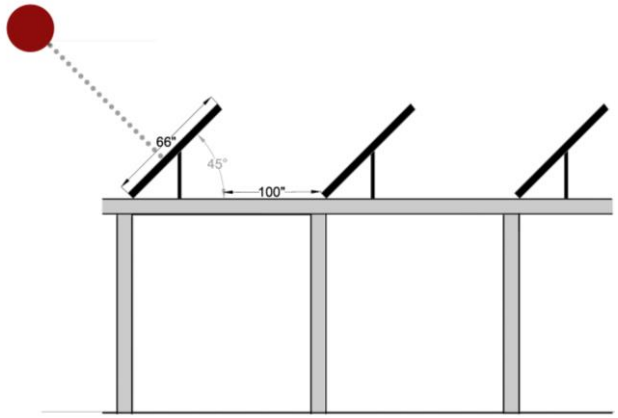




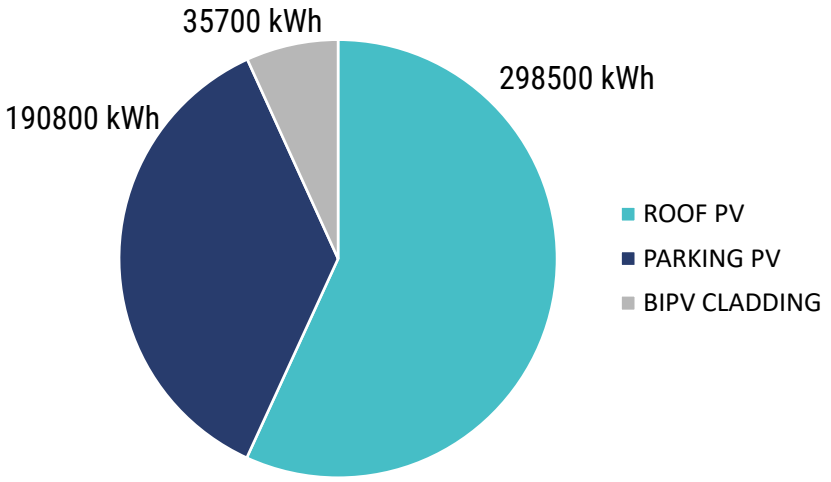
Solar energy generation

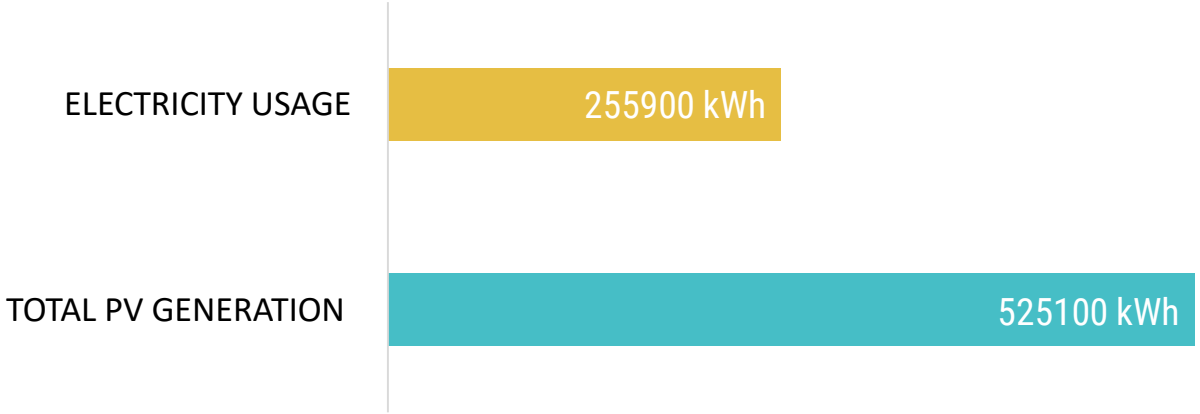


Solar PV strategy



Roof + parking PV fixed tilt angle: 45°





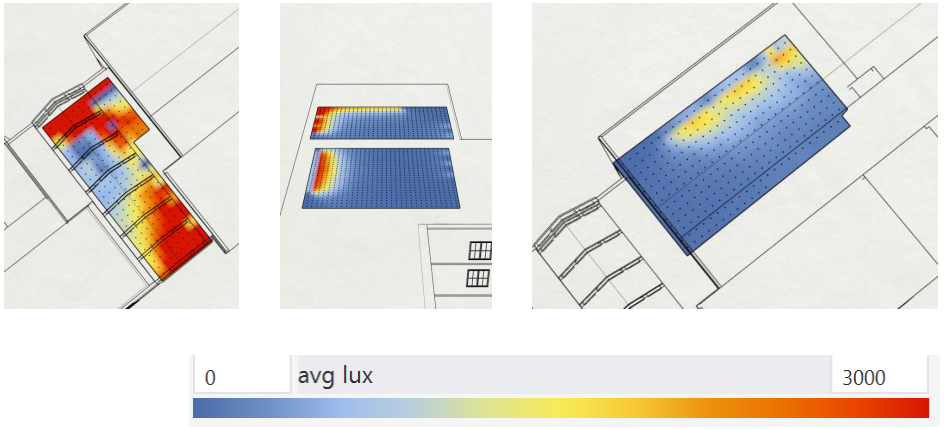
Excess electricity generation: 269200 kWh annually

IEQ
Daylighting

- Architecture
- Engineering
- **Comfort and Environmental Quality**
- Energy Performance
- Embodied Environmental Impact
- Durability and Resilience
- Market Analysis
- Occupant Experience

Considerations in design

- Removing old and toxic materials
- Providing thermal and air quality comfort
- Providing acoustic comfort
- Providing access to daylight

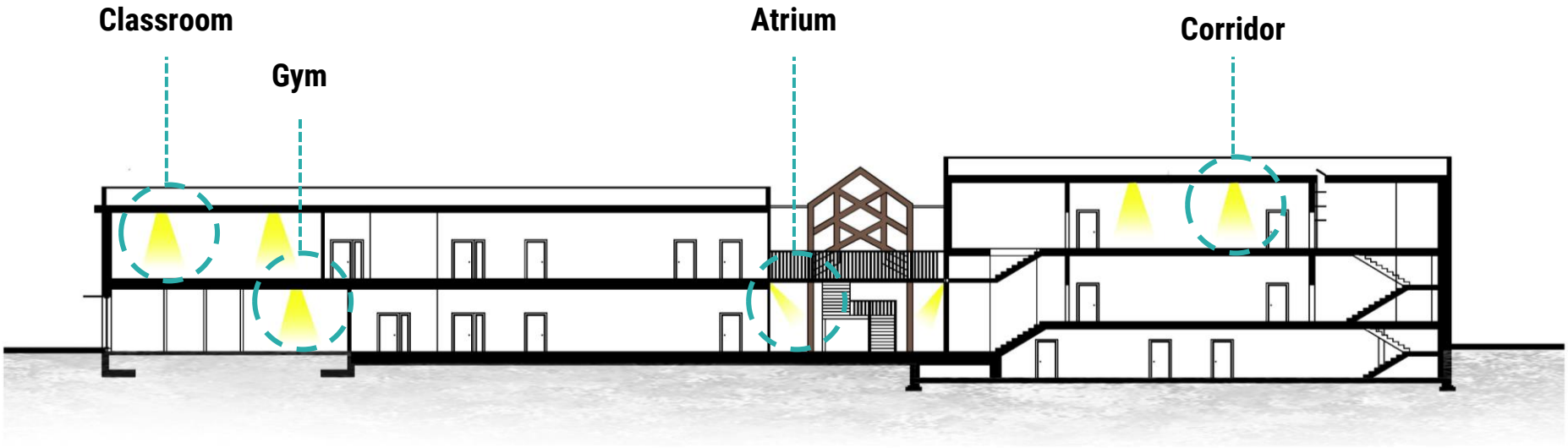


Load Reduction
Energy Strategy

- **Architecture**
- **Engineering**
- **Comfort and Environmental Quality**
- **Energy Performance**
- **Embodied Environmental Impact**
- **Durability and Resilience**
- **Market Analysis**
- **Occupant Experience**

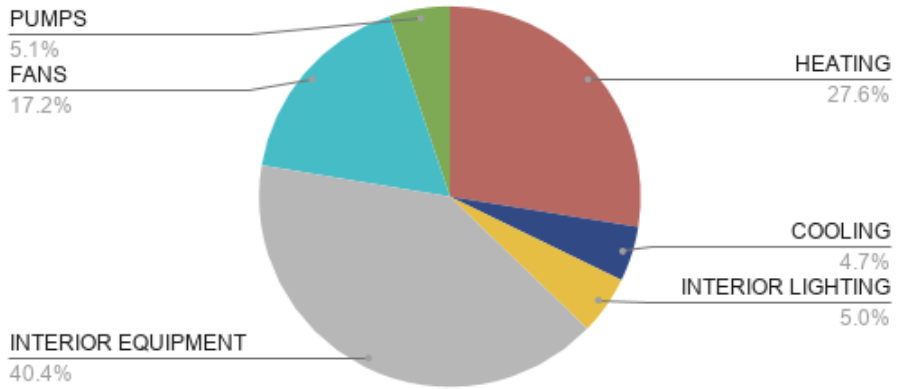
Plug + lighting load reduction strategies

- Efficient fixtures
- Occupant sensing controls
- Scheduling
- Daylight harvesting
- Sustainable use learning



Energy use intensity

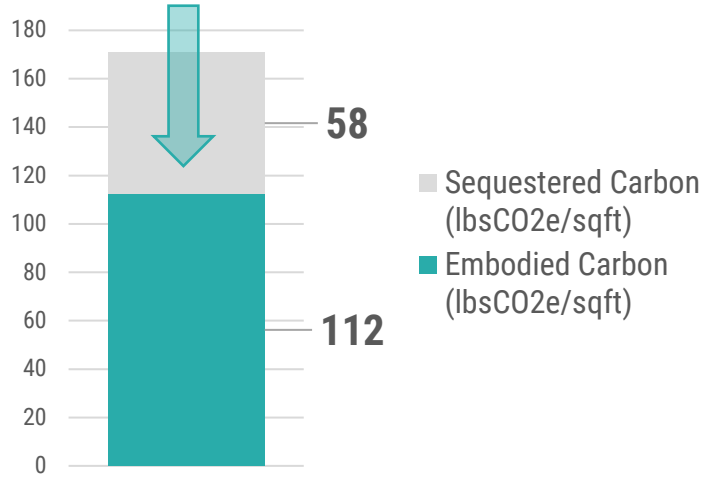
Site EUI	**23 kBTU/sqft/yr**
TGS, Tier 3	32 kBTU/sqft/yr
Competition requirement	57 kBTU/sqft/yr

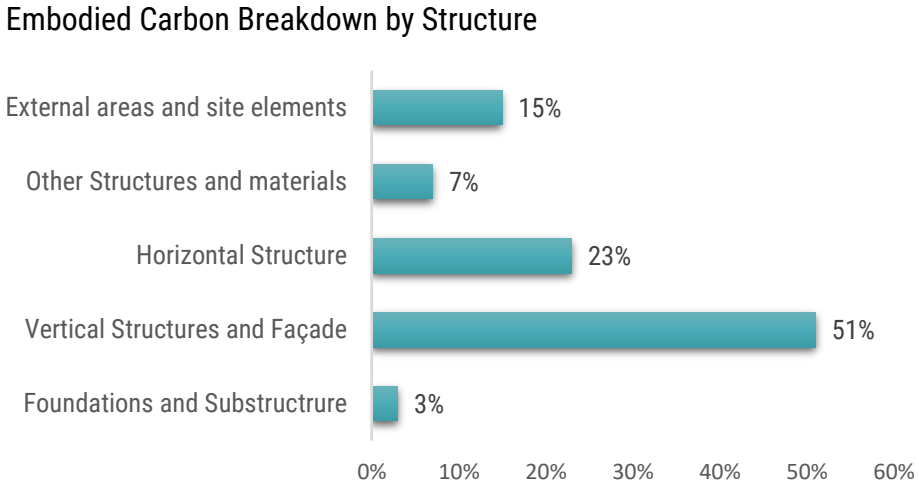


Architecture
Engineering
Comfort and Environmental Quality
Energy Performance
Embodied Environmental Impact
Durability and Resilience
Market Analysis
Occupant Experience

Minimizing carbon emissions

1. Operational carbon minimized by using renewable energy systems.
2. Embodied carbon minimized by using mass timber and other low-carbon materials.





Life Cycle Assessment using One Click LCA

Materials recovered: 33%
Materials returned: 77%
Building circularity score: **55%**

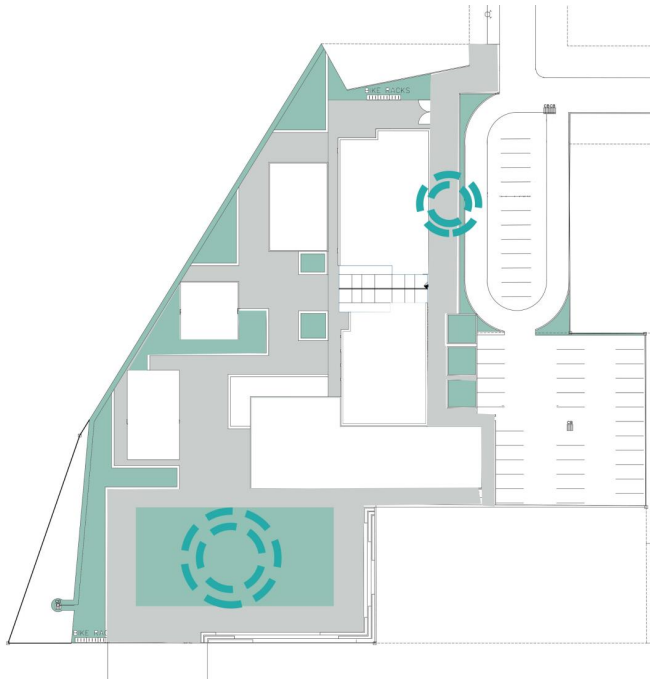
- Architecture
- Engineering
- Comfort and Environmental Quality
- Energy Performance
- Embodied Environmental Impact
- **Durability and Resilience**
- Market Analysis
- Occupant Experience

Durable and resilient design against…

Future weather patterns
- Above-code insulation
- Vapour open masonry walls against freeze-thaw

Fire emergencies
- Fire-rated materials
- Emergency exists
- On site muster points

Resource shortage
- Emergency water storage in basement



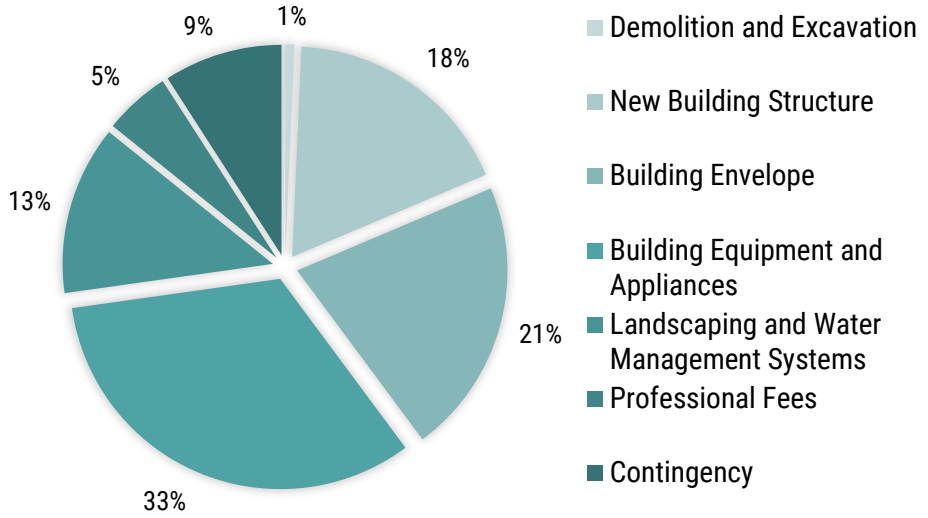
On-site muster points

Architecture
Engineering
Comfort and Environmental Quality
Energy Performance
Embodied Environmental Impact
Durability and Resilience
Project Costs
Financial Feasibility
Market Potential
Market Analysis
Occupant Experience

Project cost: **$4.2 million USD**

$102 USD/sqft

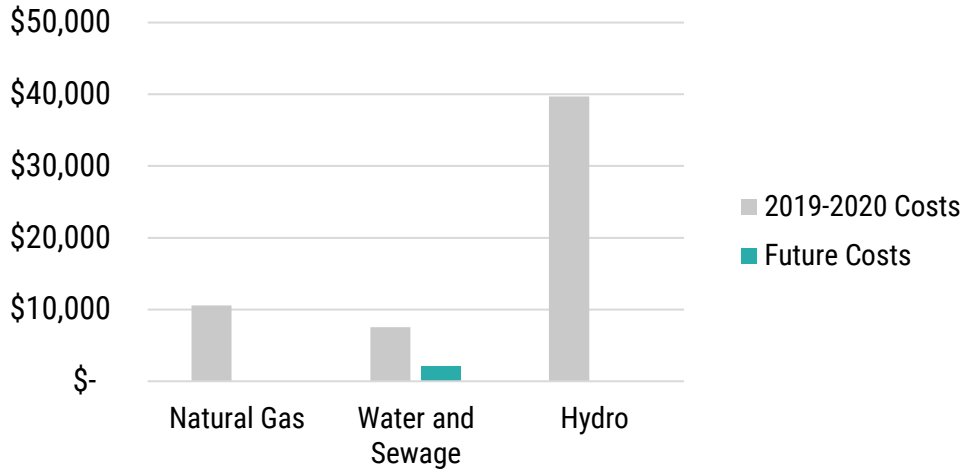
New build school:
$135 - $180 USD/sqft



Annual Utility Bill Savings: 95%

Annual Savings: $43,500 USD
Grid Cashback: $19,000 USD

Over 25 years, savings + cashback totals $1.6 million USD.



Likelihood of adoption by…

Toronto Catholic District School Board

- TCDSB Energy Conservation Plan
- Toronto targets net-zero emissions by 2050

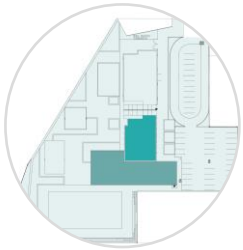
Construction industry

- Considered constructability, local and available materials, costs
- Phased 14-month timeline that keeps school in session during the year

Phase 1

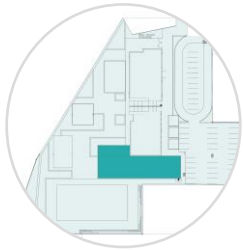
6 months
Summer - Fall

Phase 2



6 months
Winter - Spring

Phase 3



2 months
Summer

Intended occupants

Design around the goal to provide comfortable and enjoyable spaces to learn

- Architecture
- Engineering
- Comfort and Environmental Quality
- Energy Performance
- Embodied Environmental Impact
- Durability and Resilience
- Market Analysis
- Occupant Experience

User experience:

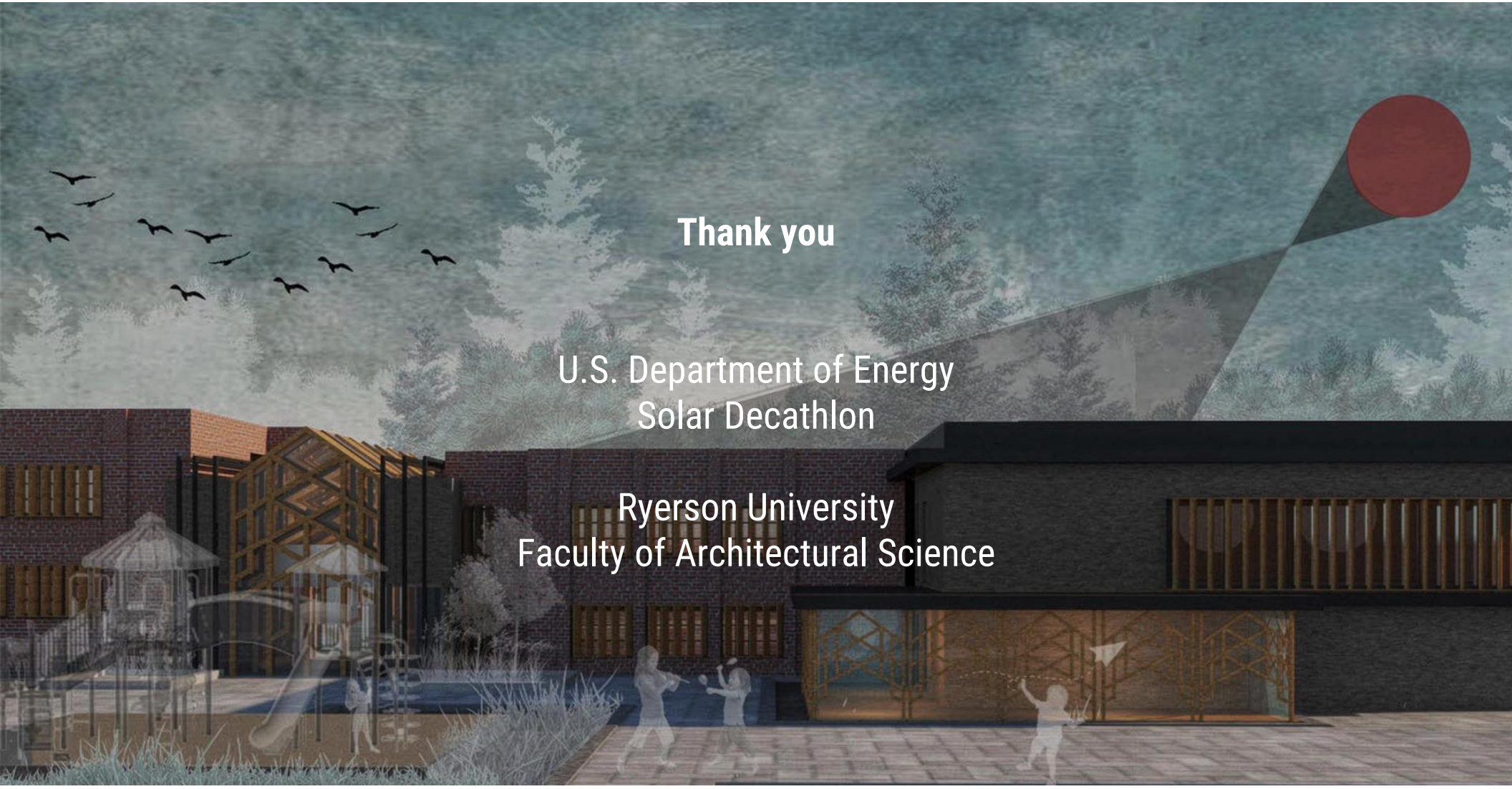
- Safe + inclusive design
- Biophilic design
- Preservation of history and traditions

Learning experience:

- Learning stations
- Vegetable gardens
- Community partnership

Outdoor study space

Evergreen Brick Works



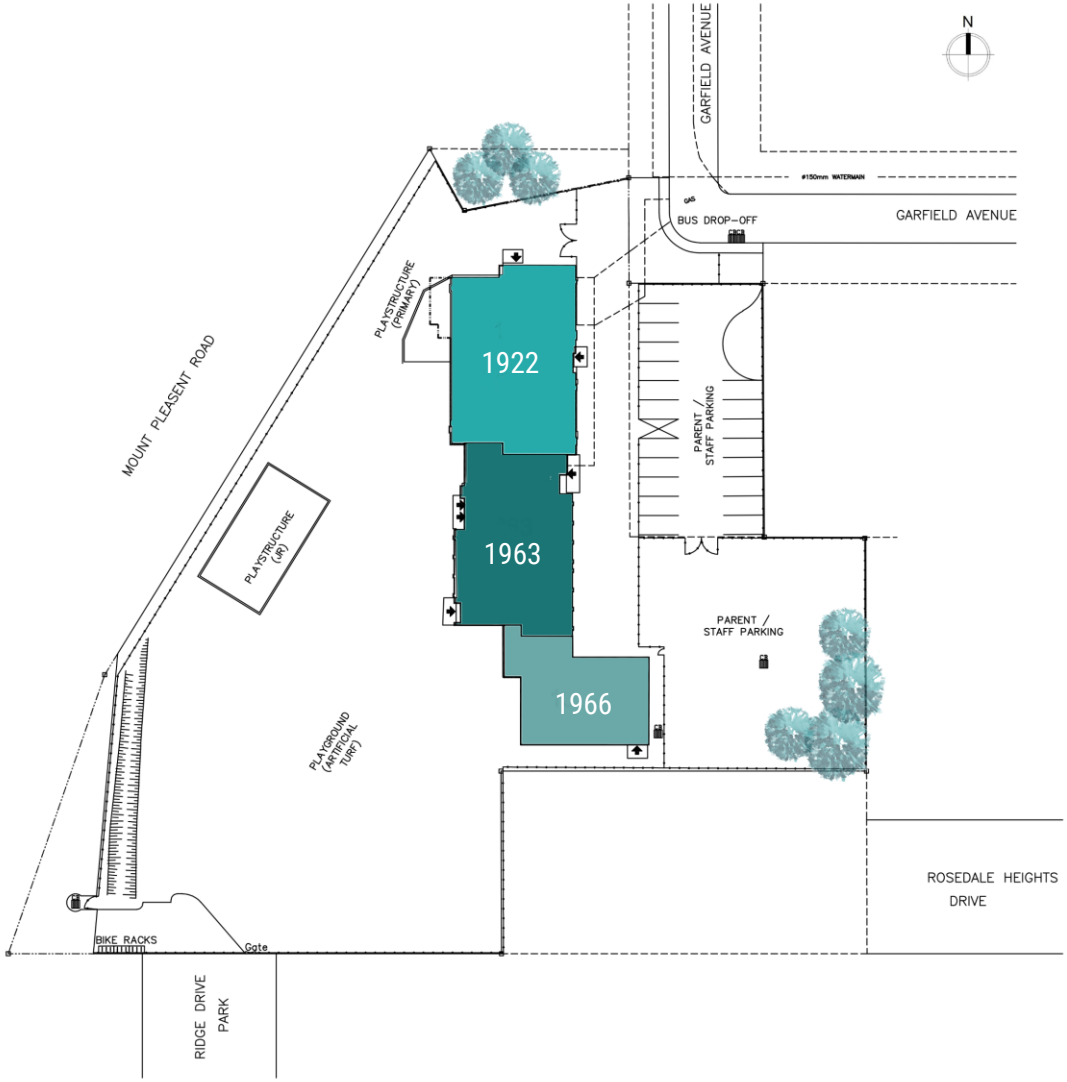
Thank you

U.S. Department of Energy
Solar Decathlon

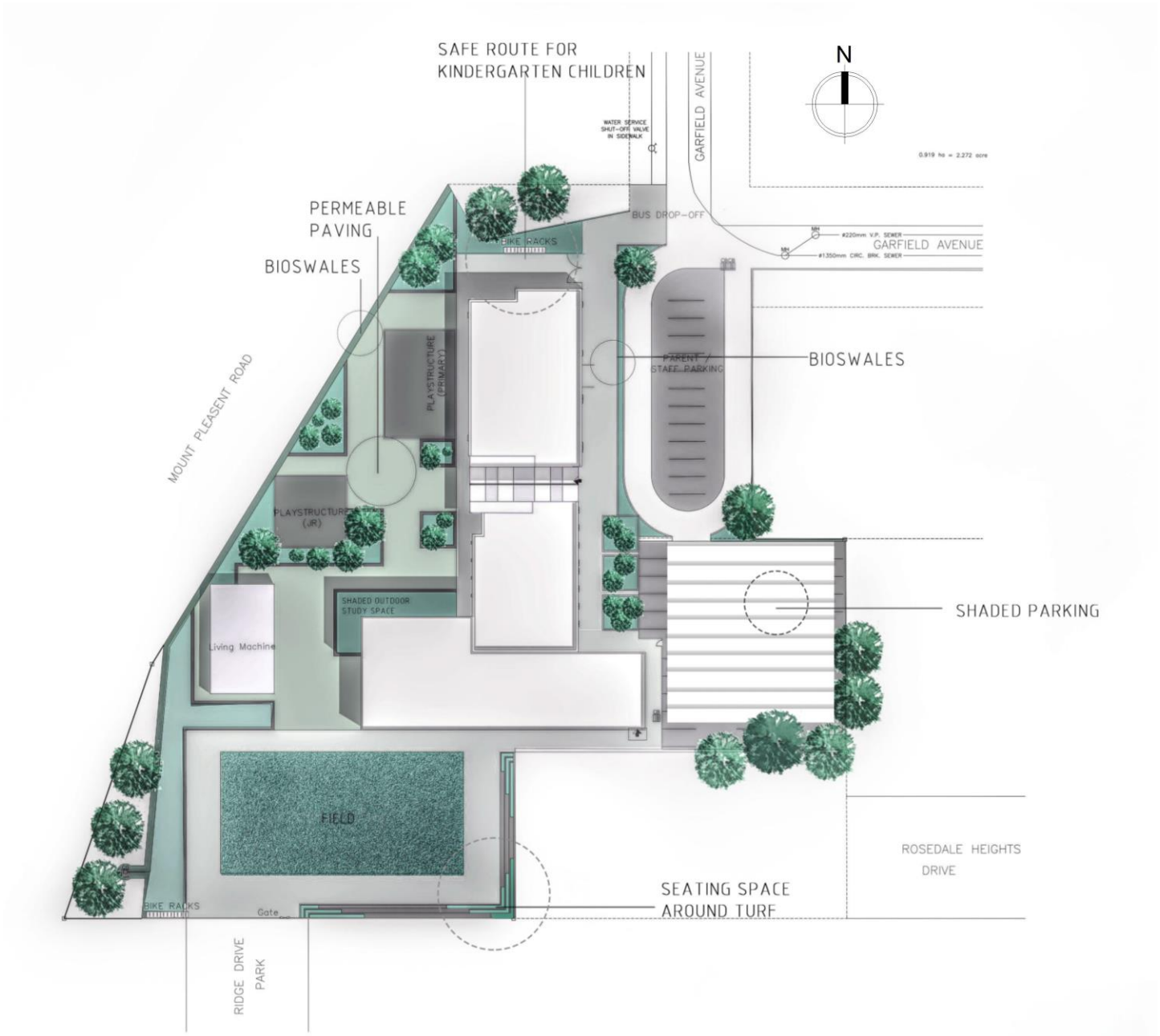
Ryerson University
Faculty of Architectural Science

Supplementary Slides

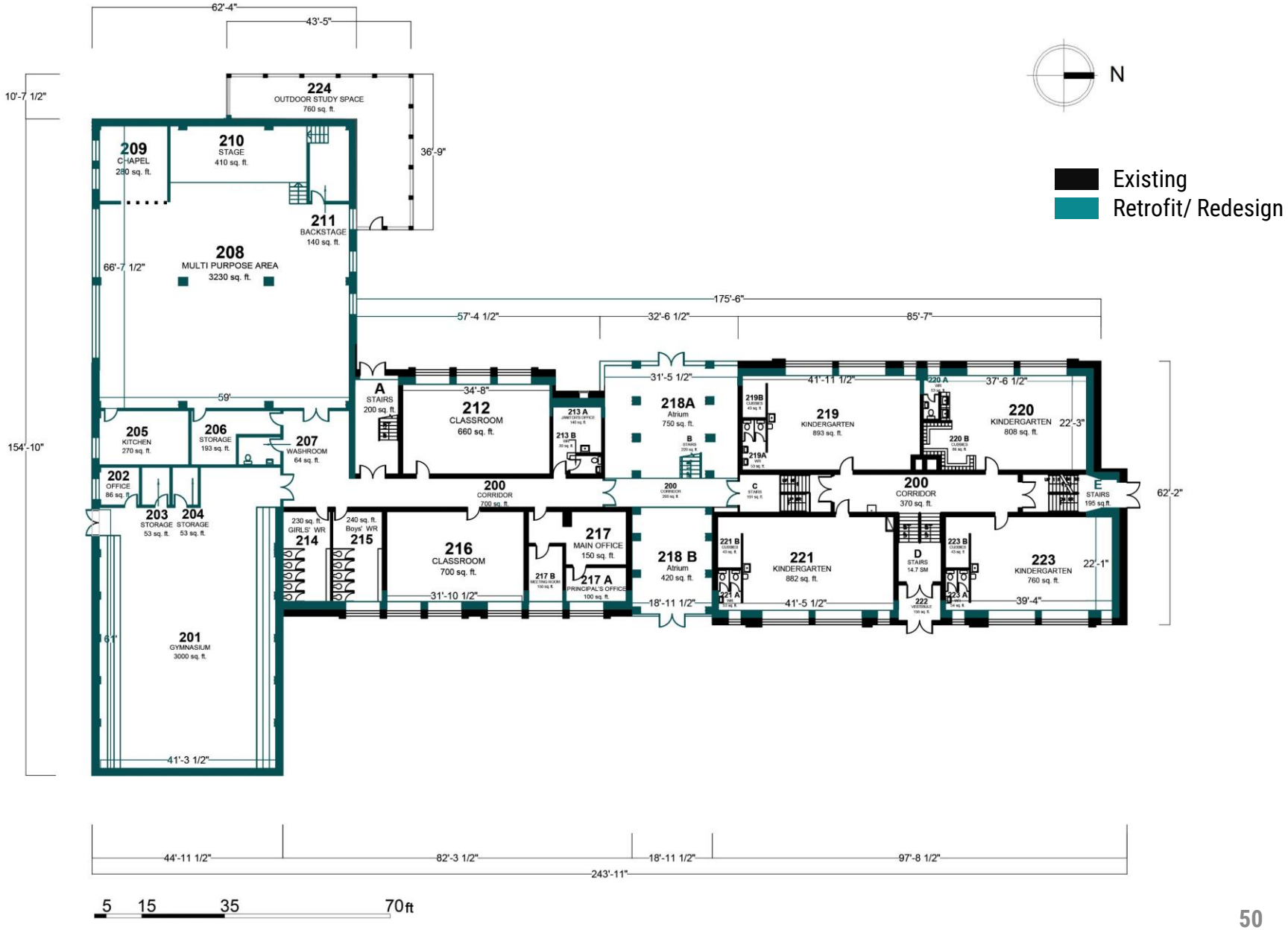
Existing School Site Layout



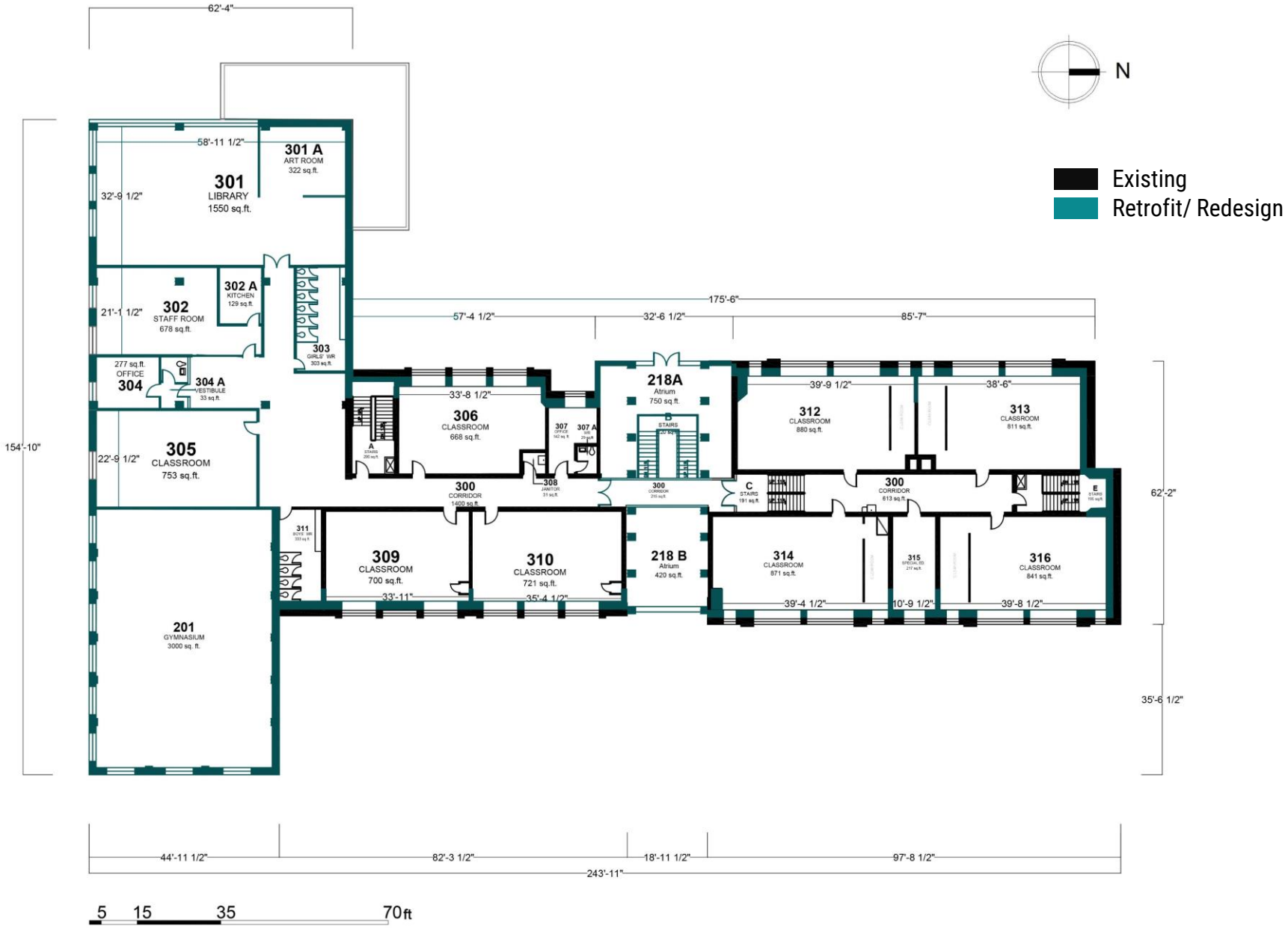
Redesigned Site Layout



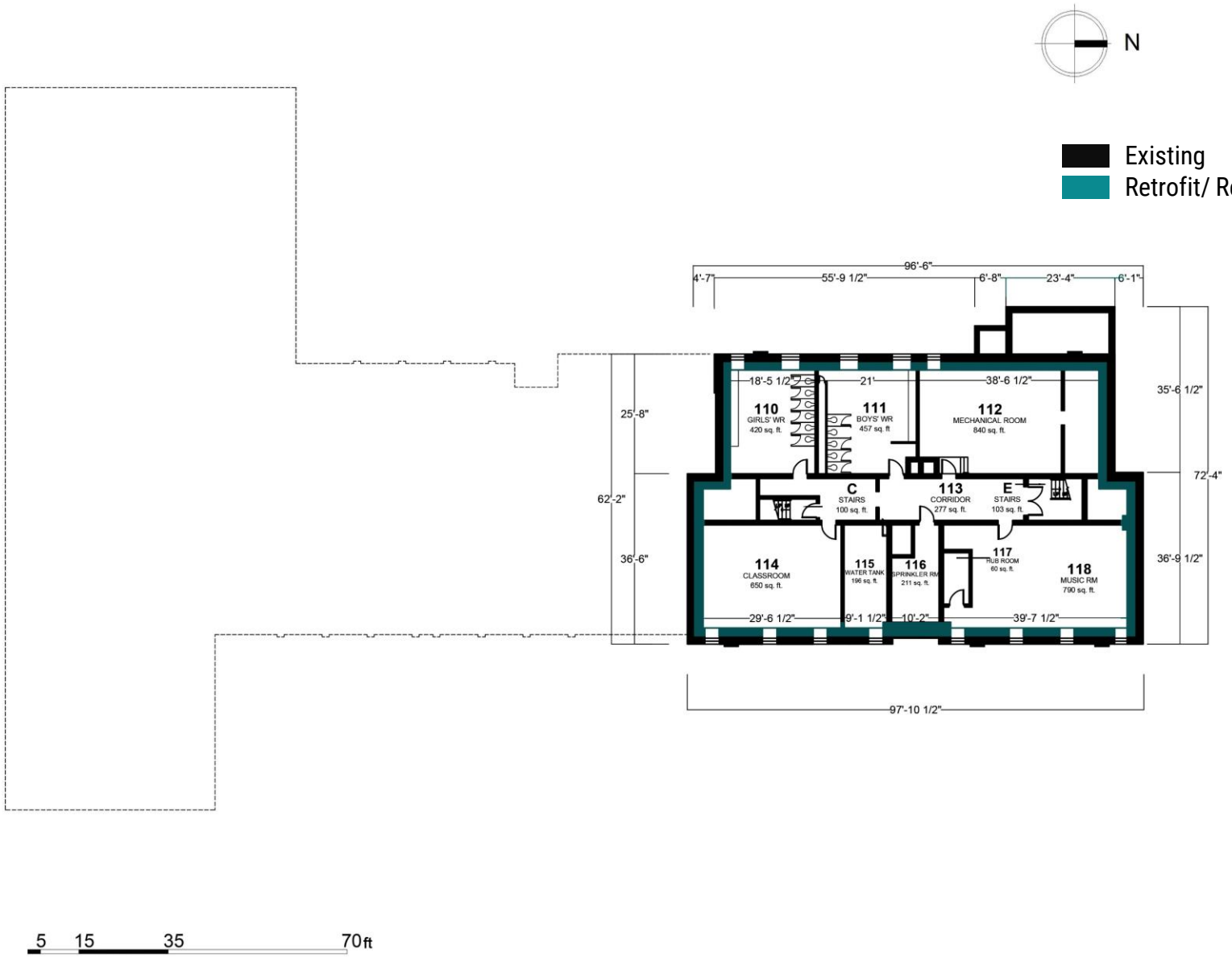
Ground Floor Plan



First Floor Plan



Basement Floor Plan



Elevations

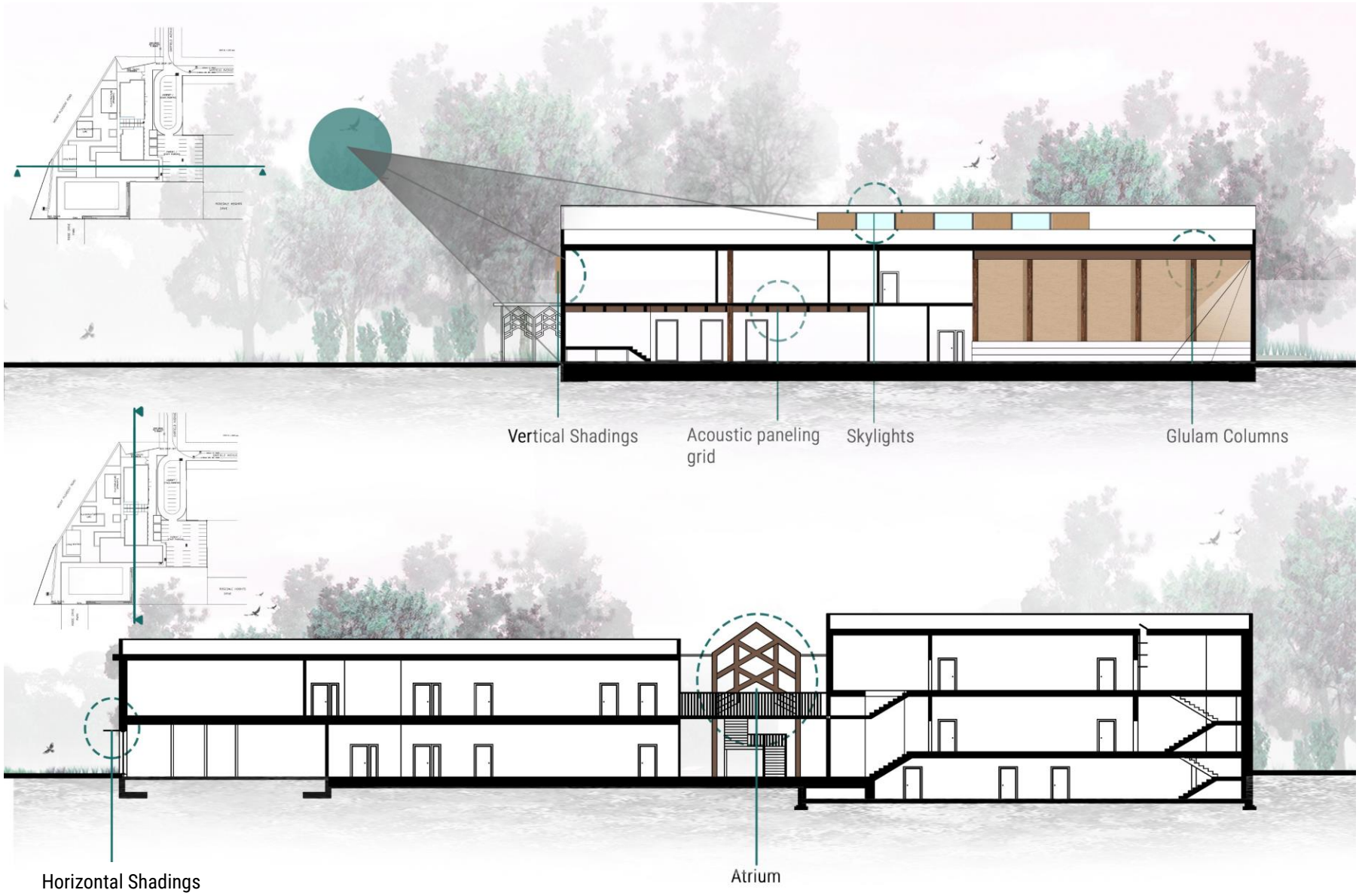
North Elevation

South Elevation

West Elevation

East Elevation

Sections


Vertical Shadings
Acoustic paneling grid
Skylights
Glulam Columns
Horizontal Shadings
Atrium

Multipurpose Area

Outdoor Study Space

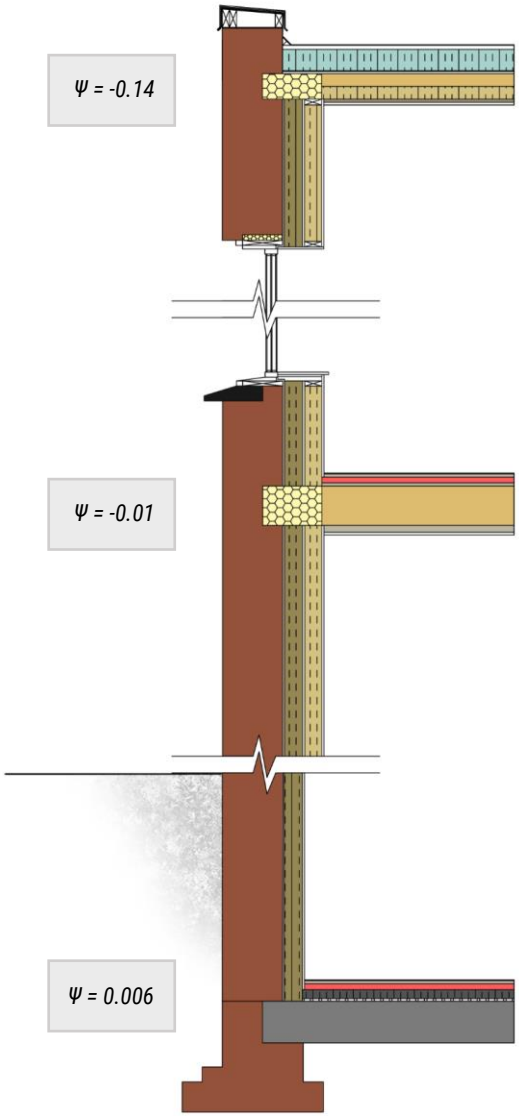
Retrofit Considerations

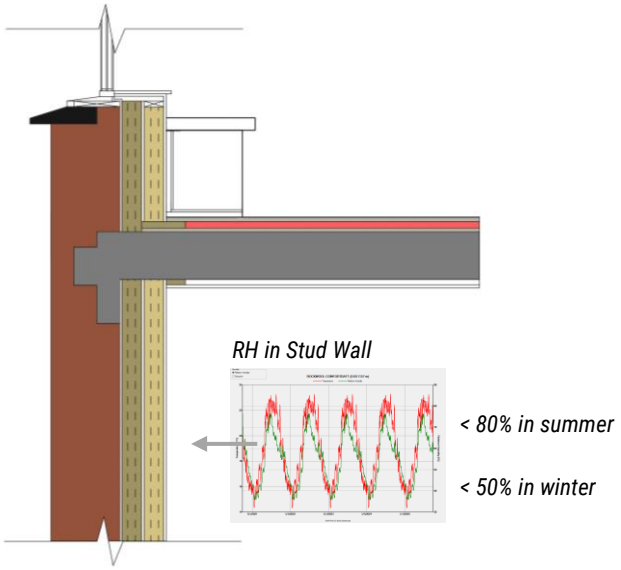
- Poor insulation
- Poor water shedding
- Cracked mortar

- Uninsulated basement slab causes moisture problems
- Double-glazed aluminum windows also cause child safety hazards

- Preserving brick façade

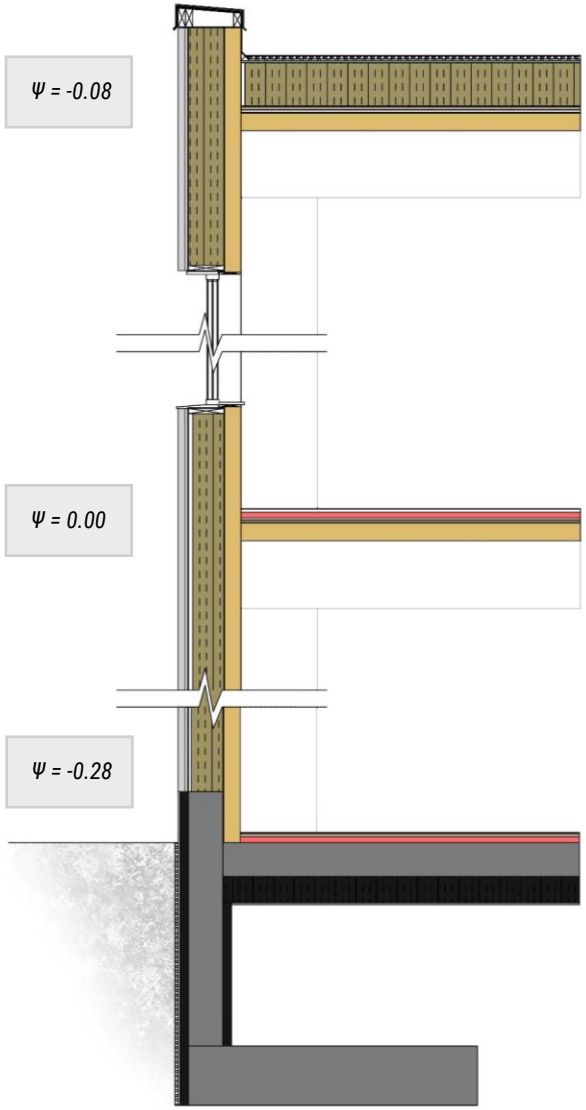
Retrofit Envelope





Walls Above Grade	**R-38**
Walls Below Grade	**R-22**
Ground Slab	**R-17**
Roof	**R-42**
Glazing	**R-4.5**

New Extension Envelope



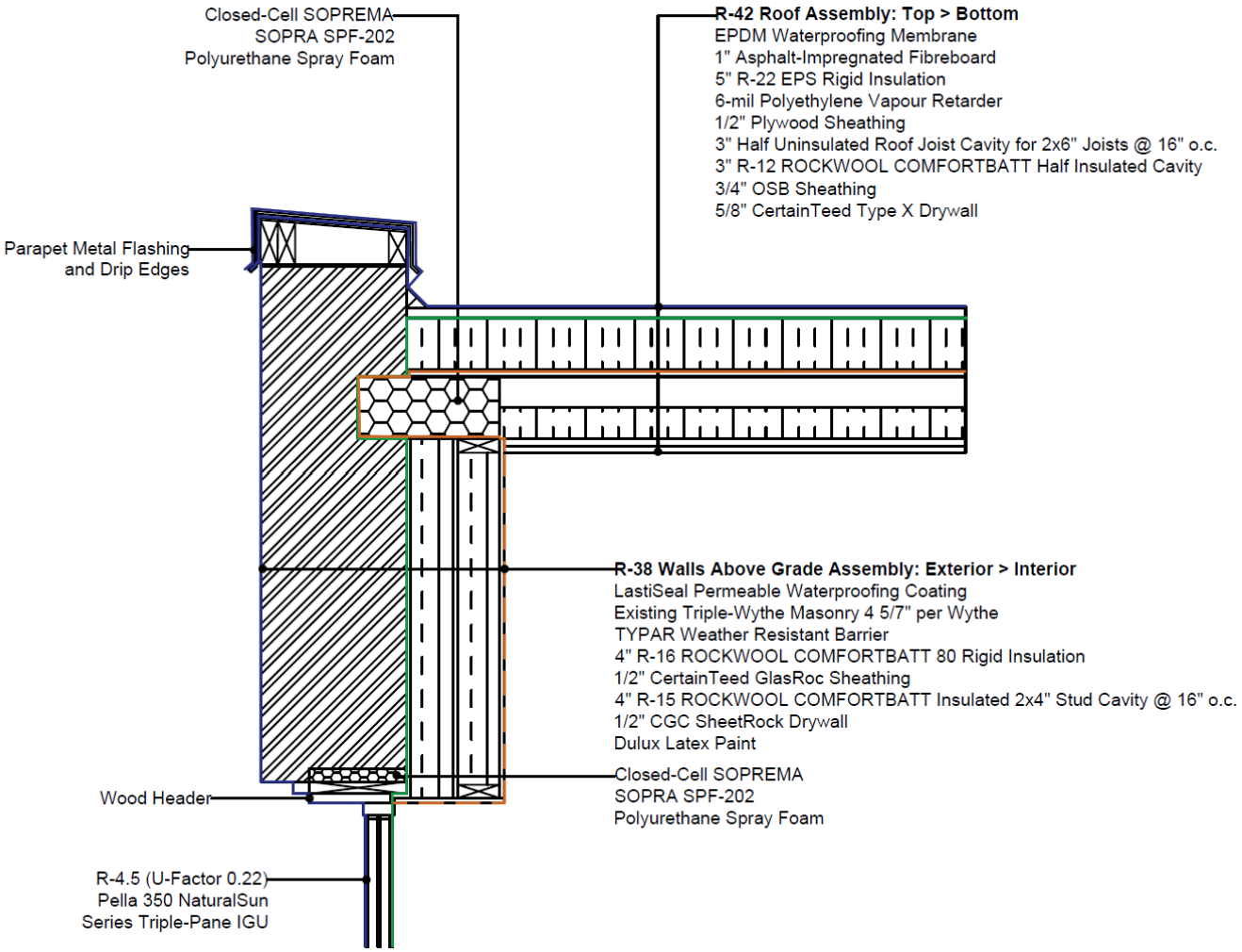
Walls Above Grade	**R-41**
Ground Slab	**R-37**
Roof	**R-52**
Glazing	**R-5.0**
Foundation Walls	**R-22**

Glazing

- Argon-filled triple-glazed low-e units
- Double-hung with locked bottom sashes for child safety
- Operable skylights in atrium

- U-factors between 0.04 to 0.06 BTU/hsqft
- SHGC of 0.46 for passive solar heating
- SHGC of 0.23 for south façade and atrium

Envelope Sections: Retrofit Wall to Roof



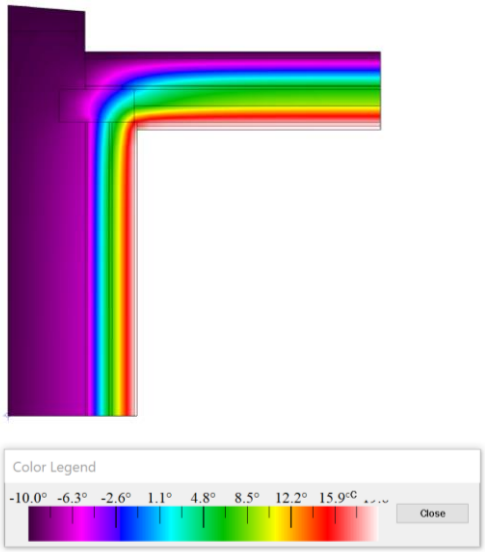
Assembly Control Layers

- Primary Bulk Water
- Air and Secondary Bulk Water
- Class II Vapour Semi-Impermeable
- Class III Vapour Semi-Permeable

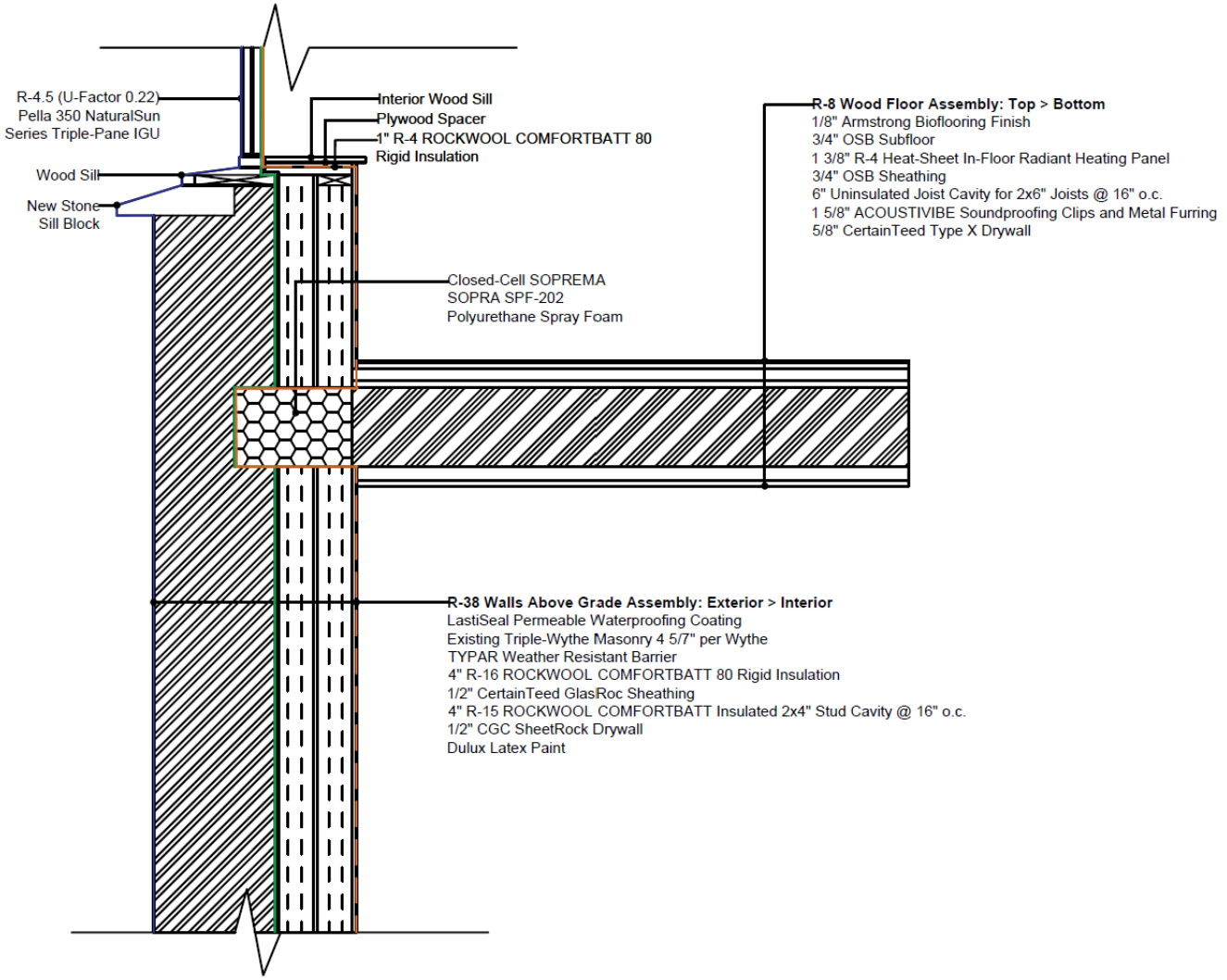
THERM Thermal Bridging Analysis

Component	U-Value (BTU/hft2F)
2-D	0.276
Vertical	0.026
Horizontal	0.026

Ψ-Factor = -0.14 BTU/hftF
Lowest Interior Surface Temperature = 32.2F (17.9C)



Envelope Sections: Retrofit Wall to Wood Floor



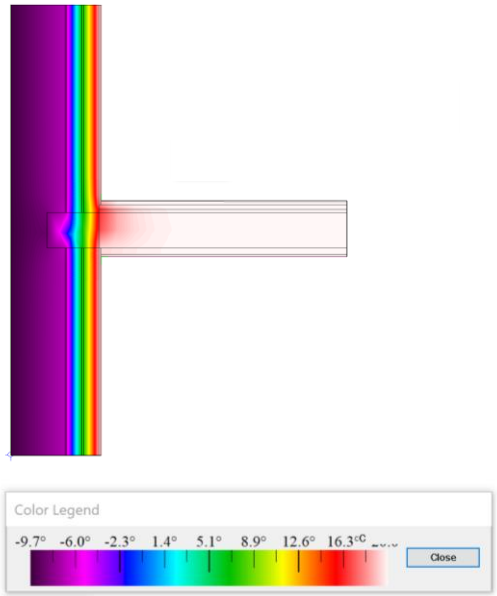
Assembly Control Layers

- Primary Bulk Water
- Air and Secondary Bulk Water
- Class II Vapour Semi-Impermeable
- Class III Vapour Semi-Permeable

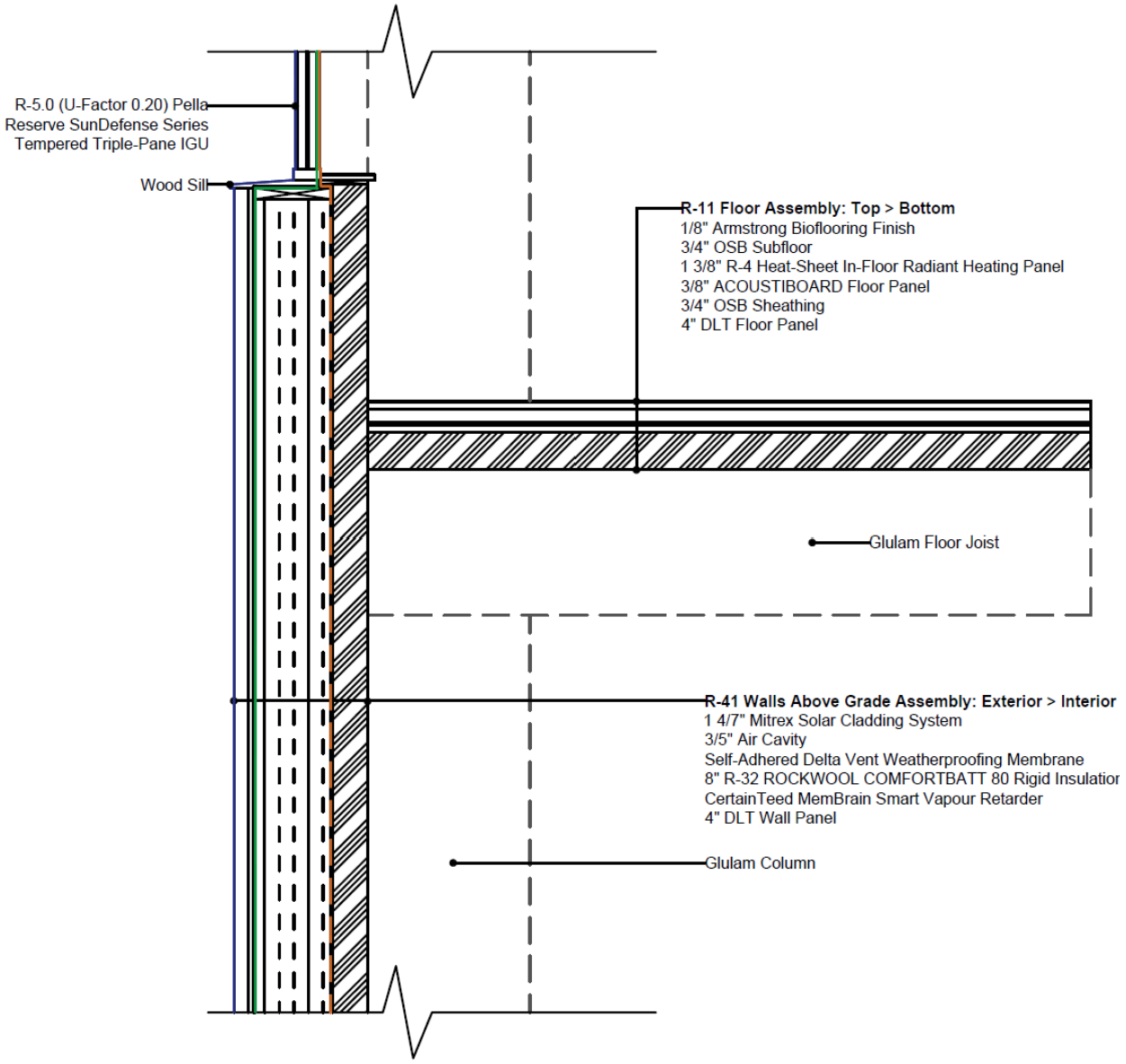
THERM Thermal Bridging Analysis

Component	U-Value (BTU/hft2F)
2-D	0.013
Vertical	0.026
Horizontal	0.117

Ψ-Factor = -0.01 BTU/hftF
Lowest Interior Surface Temperature = 34.0F (18.9C)



Envelope Sections: Extension Wall to Floor



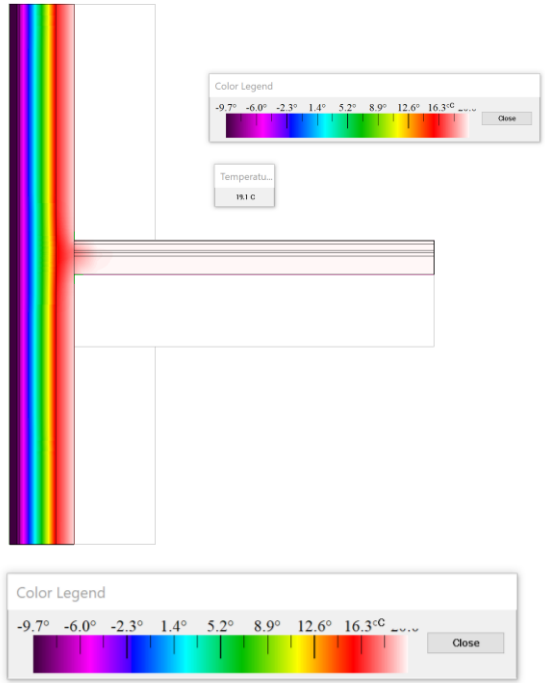
Assembly Control Layers

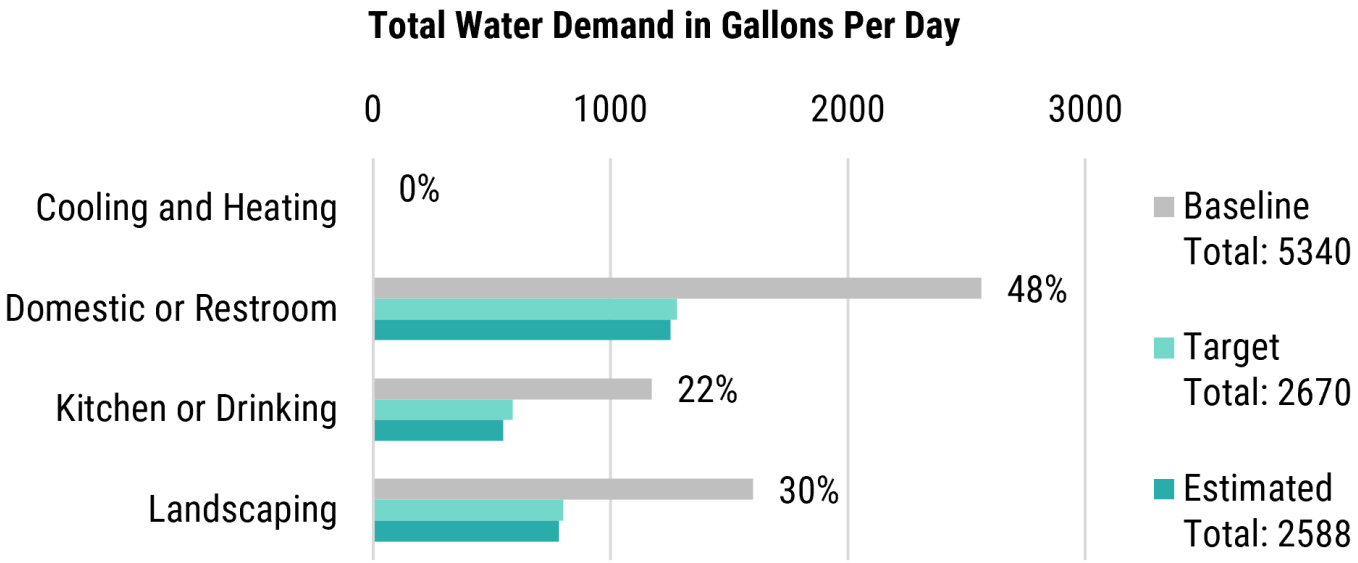
- Primary Bulk Water
- Air and Secondary Bulk Water
- Class II Vapour Semi-Impermeable
- Class III Vapour Semi-Permeable

THERM Thermal Bridging Analysis

Component	U-Value (BTU/hft2F)
2-D	0.010
Vertical	0.022
Horizontal	0.092

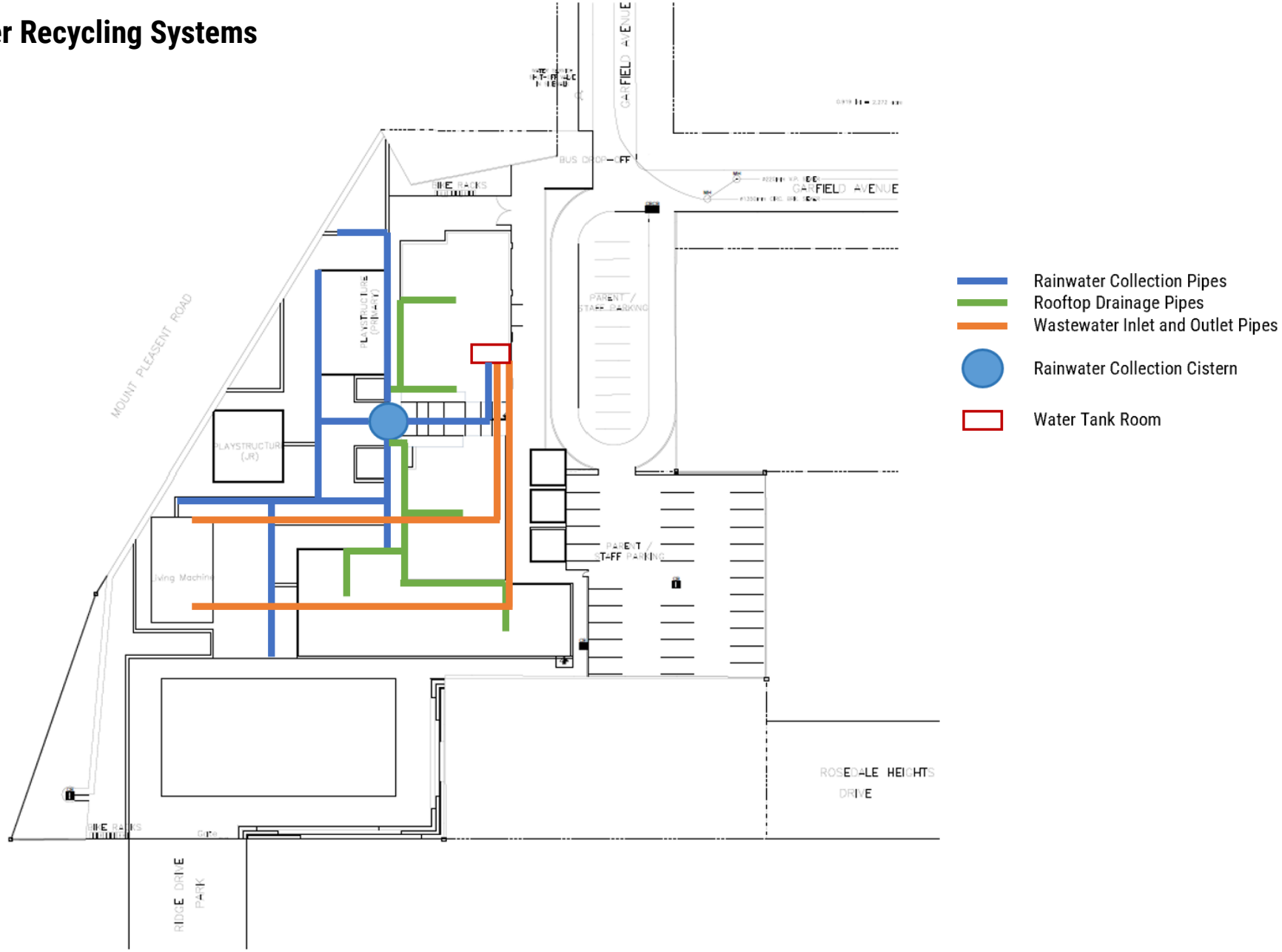
Ψ-Factor = 0.00 BTU/hftF
Lowest Interior Surface Temperature = 34.4F (19.1C)



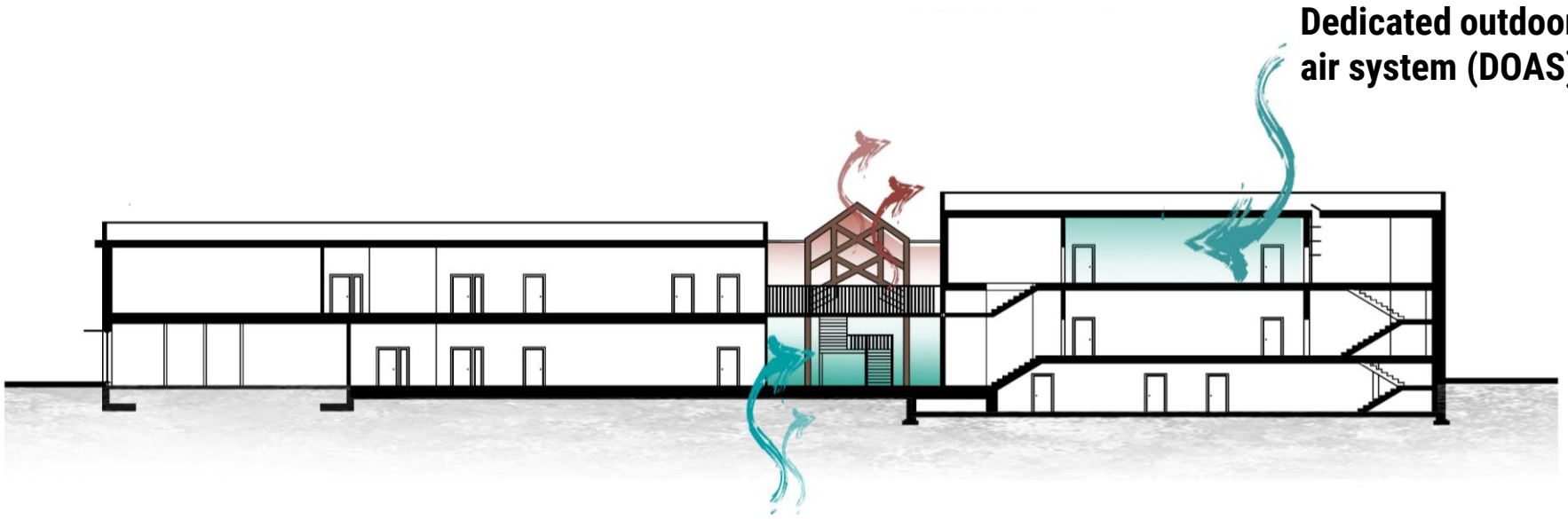


New fixtures achieve a **52% reduction** in potable and non-potable water use, meeting Toronto Green Standards Tier 3.

Water Recycling Systems



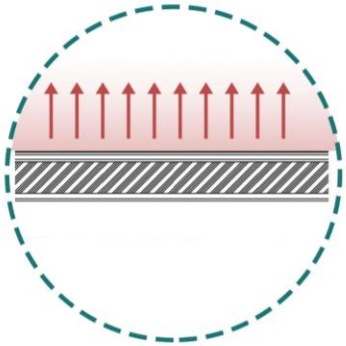
Hybrid ventilation strategy



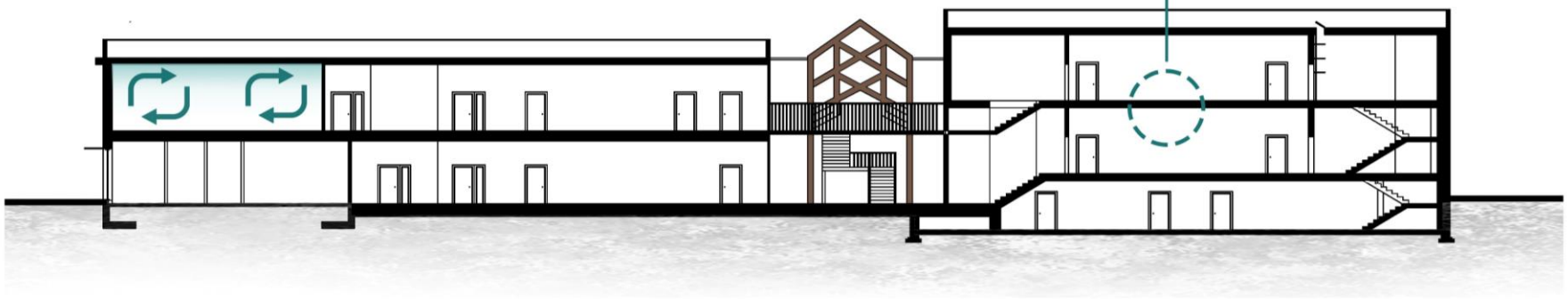
Required total outdoor air rate **13800 cfm** or **2.13 ACH**

Heating + cooling

Radiant in-floor heating



Fan-coil units in select zones

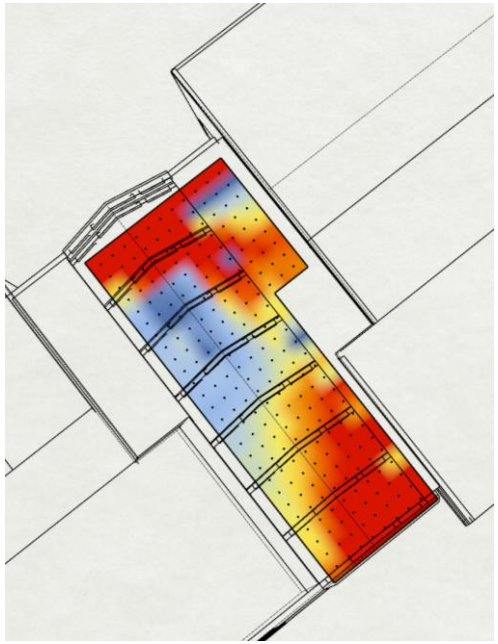


Cooling loads driven down by:

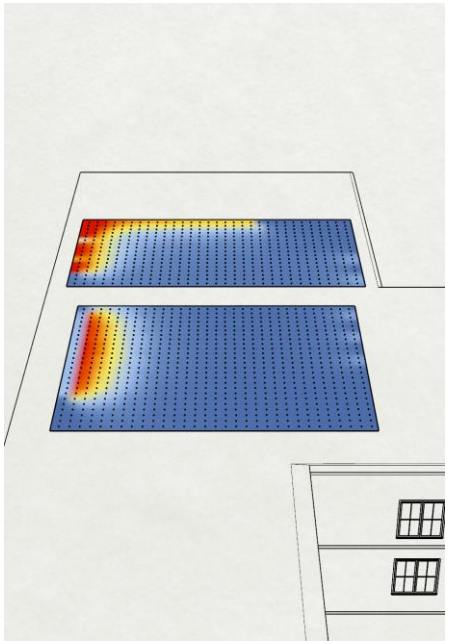
- DOAS cooling coil
- Window shadings
- Roof PV shading
- Operable windows

Peak heating load	**220 kBTU/hr**
Peak cooling load	**110 kBTU/hr**

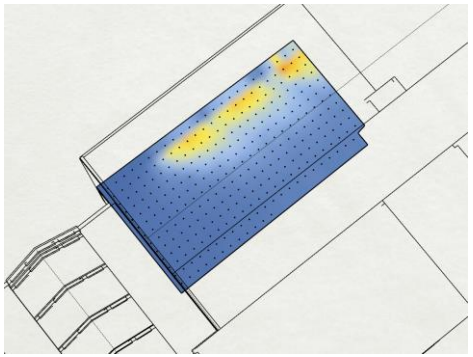
Daylighting

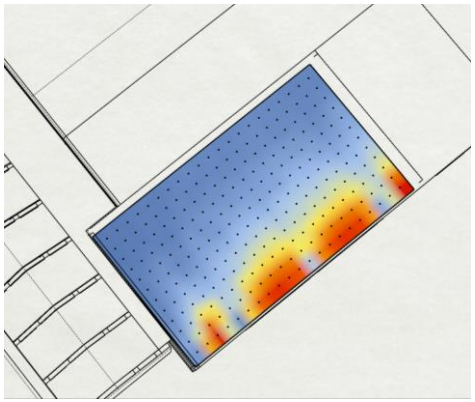


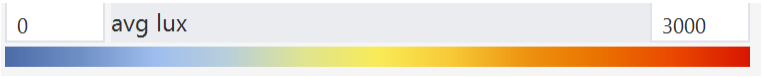
Atrium Annual Average: 3540 Lux



Library Annual Average: 500 Lux
Multipurpose Annual Average: 250 Lux

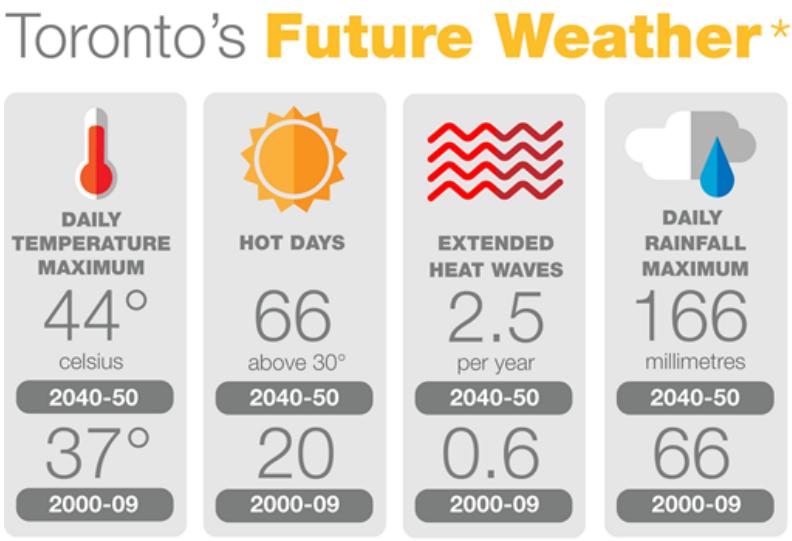






Second-Floor East and West Classrooms
Annual Average: 400 to 700 Lux

Resilience Against Future Weather



Changing Weather Patterns

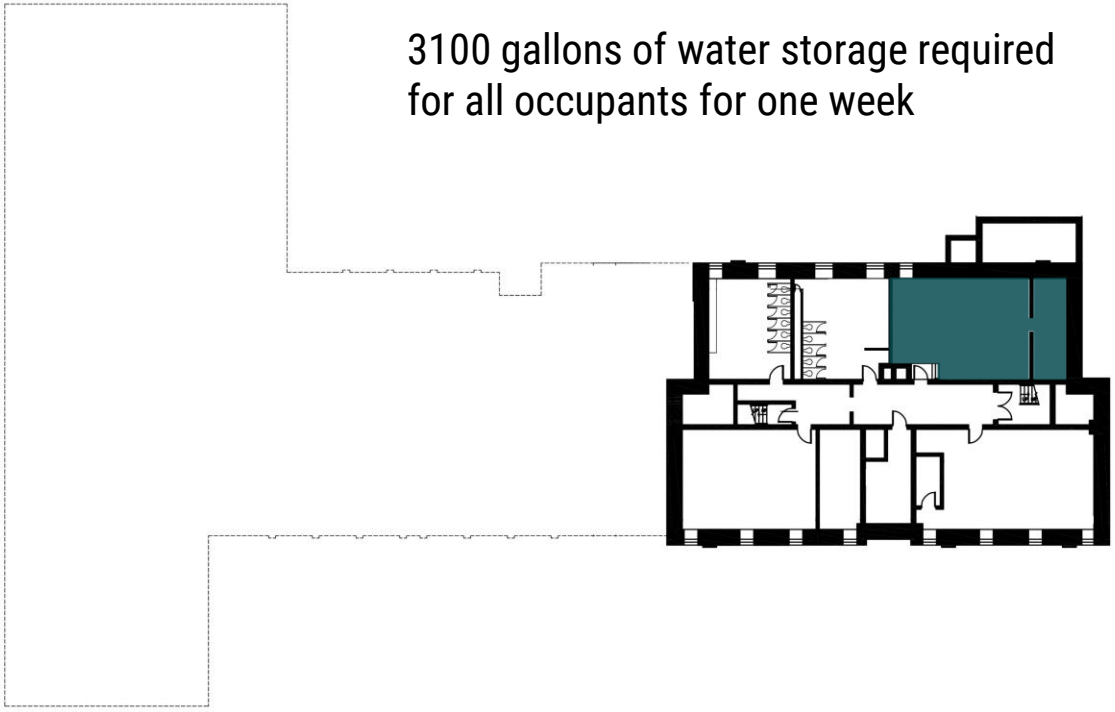
- Increasing temperatures
- Fewer snow events
- More summer storm precipitations
- More frequent heat waves

Effects

- Overheating risk
- High wind driven rain
- Snow loads
- Freeze-thaw deterioration

Water Resiliency

3100 gallons of water storage required
for all occupants for one week



Fire Emergencies